Assiniboine Community College

LAND MANAGEMENT AND CROP PRODUCTION

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Developed in cooperation with
MANITOBA AGRICULTURE

ASSINIBOINE COMMUNITY COLLEGE

FORWARD

Over the years, a number of books similar to this one have been prepared for use by students in Agriculture. There have been many contributing authors and countless hours of research have gone into each edition. The 1985 edition is a revision of the 1976 edition which was compiled by the Manitoba Department of Agriculture. This book draws very heavily on the previous one, although every effort was made to update all of the subjects covered. A complete section on grain drying has also been added to this edition.

A great deal of credit and thanks go to the following people who helped update this book:

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and the many contributers to the Manitoba Department of Agriculture's FACTSHEETS.

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I. SOILS

Soil is a mixture of organic and mineral material, living soil organisms, water and air. It is the upper layer of material covering the earth's crust. Often it is only a few centimeters thick, seldom more than a few meters thick. The soil has been formed by the action of wind, water, frost, man, vegetation and soil organisms on the original rock material covering the earth's surface. It has taken about eight to ten thousand years to form the soil that we farm today.

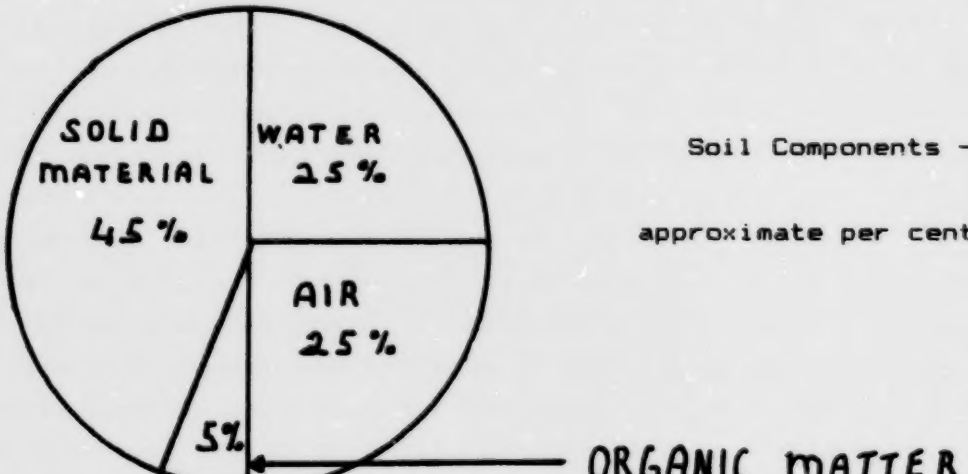
This chapter will describe the origin of the original rock material from which the soil is formed. It will also discuss some of the major parts of soil that are important for crop production.

A. Origin of Soil Materials

All soil materials originally came from different types of rock that were exposed on the surface of the earth. The types of rock which were represented in Manitoba were limestone, sandstone, shales, and granite. Glaciers, which are huge sheets of ice hundreds of meters thick, moved across from the north to the south, scraping up rock material from the many different types represented in Manitoba. As they moved, they ground the material and mixed it together to form a mixture of rocks, boulders, pebbles, sand, silt and clay. When the glaciers melted, they left behind this material which is known as parent material, or moraine. In the northwestern and central part of Manitoba this parent material was left behind in such a way as to form gently to very steeply sloping hills and many pot holes. The smoother areas are called till plains and the steeply sloping areas are terminal moraines, or areas where the glacier melted faster than it could retreat. In the south-central part of the province, a huge lake was formed by the melting glacier. This lake is called Glacial Lake Agassiz. Many rivers from the western and eastern part of the province drained into this lake. These rivers carried soil particles that they picked up from the parent material and dumped them into this huge lake. The coarse sandy material was deposited near the shoreline which today is known as the escarpment. This runs in a

north-westerly direction through Morden to Austin and up to the Riding Mountains. On the east side of this escarpment we find the sandy material deposited, often many meters thick. The fine material took longer to settle out and was carried further into the lake. When the water finally receded, it left behind a large flat plain of very fine particles, known as clay, many meters thick. This is known as a lacustrine deposit and covers the area known as the Red River Valley.

In this fashion many thousands of years ago the parent material was deposited on the surface over top of the bedrock. In some areas the parent material is hundreds of meters thick while on other areas it is only a few meters thick. It is the action of wind, water, living organisms, plants and man over a period of time on this parent material that has created soil as we see it today. This soil is made up of water, solids, mineral particles, living and dead organic material and air. The diagram below shows the approximate percentage of the whole soil that each part contributes.



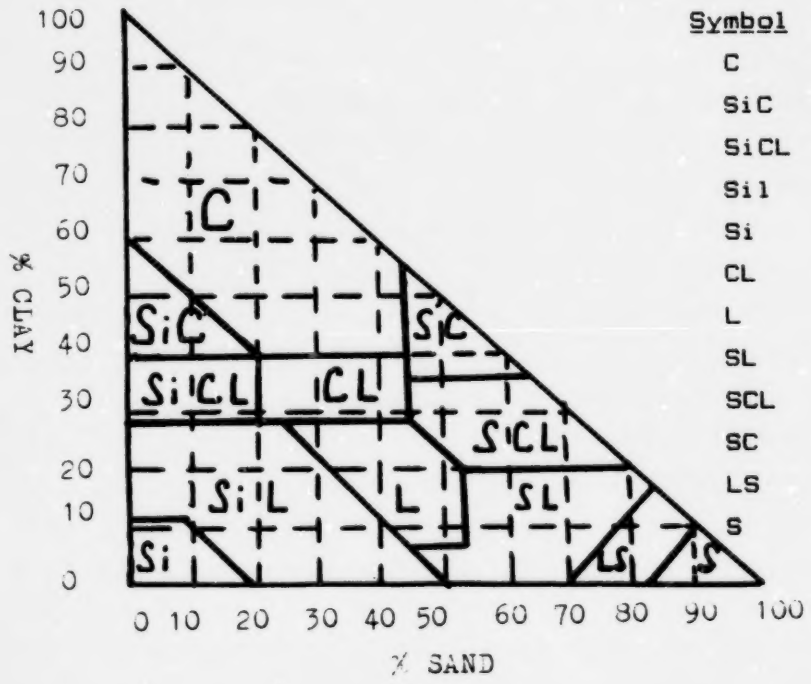
Soil Components --

approximate per centages

B. Solid Material

The mineral part of the soil is made up of very small particles of rock that are grouped into three fractions. Sand particles are the largest and can easily be seen by the naked eye. Clay particles

are the smallest and cannot be seen with the naked eye. Silt particles are between sand and clay in size and are too small to be seen by the naked eye. The proportions of sand, silt and clay particles in the soil determines the texture of the soil. There are about twelve main textural classes or textural names. Soil from each textural class has a different proportion of sand, silt and clay in it. The diagram below shows the twelve main textural classes. From this diagram it can be seen that a soil with a clay textural name can have from 40 to 100% clay particles, 0 to 40% sand and 0 to 20% silt sized particles. Thus, although the soil is called a clay texture, it may contain up to 60% non-clay particles. Many of these types of soils are found in the Red River Valley. A soil with a loam



Symbol	Textural Name
C	Clay
SiC	Silty Clay
SiCL	Silty Clay Loam
Sil	Silty Loam
Si	Silt
CL	Clay Loam
L	Loam
SL	Sandy Loam
SCL	Sandy Clay Loam
SC	Sandy Clay
LS	Loam Sand
S	Sand

Main Soil Textural Classes -- Per centage of sand and clay in main textural classes of soils. The remainder of each class, up to 100% is silt.

texture has from about 5 to 30% clay, 35 to 40% sand and 25 to 45% silt. The Altona and Portage soils are typical loam soils. A soil with a sandy loam or loamy sand texture has from 70 to 100% sand, the rest being silt and clay. The Almasippi soils are typical sandy soils. The texture of a soil gives clues to several important properties of soils.

1. The texture of a soil gives a good indication of the amount of water that the soil can hold for plant use. Clay and clay loam soils can hold more water for plant use than sandy soils. This will be discussed in more detail under soil moisture.

2. The texture of the soil determines the rate at which water infiltrates and percolates through the soil after a rain or from spring melt water. Water enters or infiltrates a clay soil very slowly, causing puddles to form. It often takes two to four days for water from a heavy rain to infiltrate into a clay soil. This can cause crop losses due to drowning. Once the water enters a clay soil, it moves through the soil (known as percolation) very slowly. This prevents most of the rain water from leaching out of the root zone. Thus the water stays in the soil for the crop to use. Water infiltrates most sandy soils quite rapidly after a rain fall. This prevents crops from drowning. It also percolates through the soil rapidly. This means that more of the rainfall is lost to the crop before the crop can use the water. The water percolating through the soil can also move some nitrogen and sulphur through the soil. However, most years not enough water percolates through the soil to cause any great losses of nutrients.

3. Soil texture partly determines the natural fertility of a soil, especially potassium. Clay, clay loam and loam soils usually have sufficient potassium for plant growth. Sandy loam, loamy sand and sandy soils usually are potassium deficient for plant growth. When sandy soils are well drained and do not have a water table within 90 to 150 cm from the surface, they can also be sulphur deficient for canola and legumes. Usually clays, clay loams and loams are more fertile than sandy soils when no fertilizer is added.

4. The texture of the soil determines the ease with which implements can be drawn through the soils. Clay soils usually take more power to draw implements through than loam or sandy soils. This is so because clay particles tend to be very sticky when wet and forms large, hard clods when dry. Sand particles are not sticky when wet nor do they form hard clods when dry.

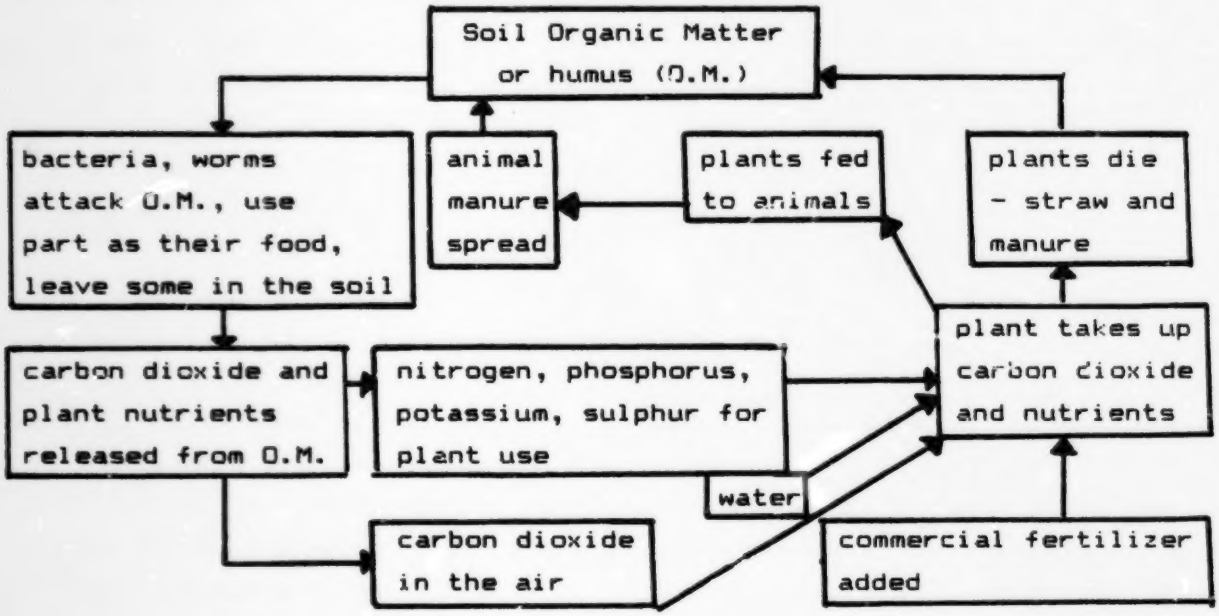
The way in which soil particles cling together to form aggregates is called structure. Clay particles, for example, tend to cling tightly together and resist separation. As organic matter in the soil decomposes to humus, many other compounds are released which "glue" soil particles together. When individual soil particles are aggregated they form larger relatively stable primary structures. If the individual aggregates are distinct and clearly separated from one another, the soil is said to have well developed structure. But if the fine clay and organic particles are dispersed throughout the soil, the result may be a poorly developed structure. Most sandy soils fall into this category because there is so little clay and organic matter in it to "glue" the particles together. If there are no visible aggregates at all, the soil is structureless.

Structure has a significant effect on soil water properties, as well as the soil's ability to resist erosion. Good soil structure increases the porosity of a soil. This is most important in clay soils which often have such poor internal drainage that water puddles on the surface. Good soil structure increases aeration, permits easier root penetration and drainage of excess water, all of which are necessary for satisfactory plant growth. Conversely, poor soil structure can limit the production of crops. Hard, massive cloddy suface soil affects seed bed preparation and often results in poor germination. Dense compact massive subsoil structure may limit root and moisture penetration.

C. Organic Matter

The second component or part of the soil is the organic matter and bacteria. Plants, soil animals such as earth worms, bacteria living in or on the soil eventually die. This dead material is known

as organic matter. The bacteria and earth worms attack this organic matter and use it for their food supply. In the process of decomposing the organic matter, carbon dioxide, and plant nutrients are released. These are used by living plants again. The partly decomposed organic matter, known as humus, is responsible for the black color of our soils. The surface layer of soil contains most of this humus. This layer is often only a few cm thick, sometimes up to 25 or 30 cm as in the Portage soils. The amount of organic matter or humus in the soil depends upon the amount of organic material added to the soil in the past and the amount being added by man each year. Since organic matter is constantly being broken down or removed, as well as being added, a cycle is formed as shown below.


Soil Organic Matter or humus (O.M.)
bacteria, worms attack O.M., use part as their food, leave some in the soil
animal manure spread
plants fed to animals
plants die - straw and manure
carbon dioxide and plant nutrients released from O.M.
nitrogen, phosphorus, potassium, sulphur for plant use
plant takes up carbon dioxide and nutrients
water
carbon dioxide in the air
commercial fertilizer added

This cycle can take a long time to complete. For example, when straw or manure is added to the soil, it usually takes many months to release the plant nutrients in a form that growing plants can use. Because living bacteria are responsible for this breakdown they need warm, moist soils for their action. Thus they only attack the straw and manure in the warm periods of the year, usually late May, June, July, August and September. During a fallow year, the bacteria

breakdown much more organic matter to release nitrogen than when a crop is growing. For this reason, fallow land is usually higher in available nitrogen than stubble land. It must be remembered, though, that fallowing does not add nitrogen or any nutrient to the soil. It only changes them from the organic form to a form that plants can use easily. Fallowing is not a soil building process, it is a destructive process over a long period of time.

Organic matter is important for several reasons:

1. Organic matter, when broken down by bacteria, provides plant nutrients, mainly nitrogen but also some phosphorus, potassium and sulphur. This is one of the main reasons for the practice of summerfallowing in Manitoba. Fallow fields, when kept clean of weeds, usually have 20 to 45 kg of nitrogen available for plant growth. Stubble fields usually have less than 10 to 15 kg of plant available nitrogen. The amount of phosphorus, potassium and sulphur release in a fallow year is very small.
2. Organic matter helps to form good soil structure. It "glues" together soil particles to form larger particles, called aggregates. These range from the size of small seeds to bigger ones the size of peas. These larger particles or aggregates give the soil a loose or "friable" structure that is easier to work than a soil with poor structure. It also gives a soil larger pores between particles and thus water and air can enter the soil more readily. This is very important in clay soils because they do not allow water to percolate into or through the soil very easily. To help formation of these aggregates, it is important to return as much straw or residue to the soil each year as possible. Burning of straw may help to form a good seed bed the next year but will result in the soil losing its structure and becoming very hard to work. It also will result in a poorer soil because less nutrients will be released since less organic matter is available for breakdown.

To maintain a high level of organic matter in soils, the following farming practices are useful:

1. Continuous cropping with adequate fertilizer applied and all straw returned to the soil will result in the organic matter content

remaining at a higher level. Fallow speeds up the breakdown of organic matter. Thus the more often a field is fallowed, the lower the organic matter count gets. This is shown in the table on work done in Manitoba on a clay soil. Crops were fertilized every year.

Cropping Pattern	Organic Matter Content
Continuous cropping for 35 years with cereals	7.2%
Fallow every fourth year	4.8%
Fallow every third year	4.8%
Fallow every second year	3.7%

2. Green manure crops plowed down without harvesting add organic matter to the soil.
3. The addition of farm manure is a useful practice which is beneficial to the soil.
4. Returning all straw to the soil instead of burning or removing the straw. Methods are available for handling large amounts of straw so that a good seed bed can be prepared for the next crop.

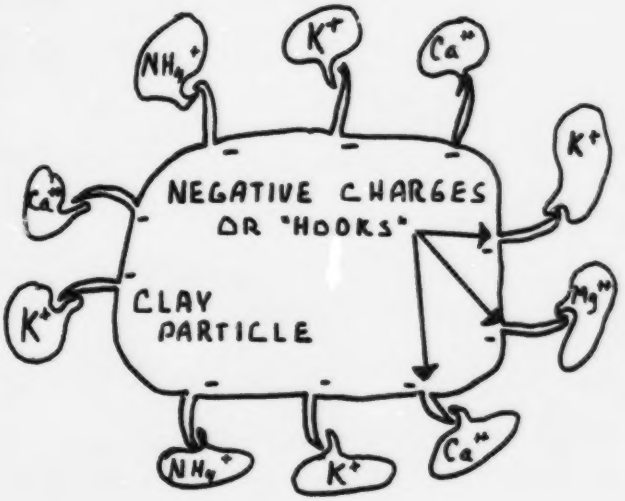
While keeping a high level of organic matter may not seem to be desirable in the short term, it is essential in the long run to keep soils in a good, productive state.

D. Cation Exchange in Soils

Soil particles and organic matter material are capable of holding nutrients against the pull of water moving or percolating through the soil. The amount of nutrients the soil can hold is known as its cation exchange capacity. Clay soils have a higher cation exchange capacity than do sandy soils, and therefore, have a greater ability to hold nutrients. This is the reason why clay soils are generally more fertile than sands.

A cation is a nutrient with a positive charge, just like a battery pole has a positive charge. Soil particles and organic

matter have negative charges. Positive and negative charges attract each other (like a magnet attracts and holds other metal objects). Therefore, positively charged nutrients (such as ammonium, potassium, calcium, magnesium and sodium) are held by soil particles. This is shown by a drawing of a clay particle as if it were enlarged thousands of times. The clay particle has negative charges or "hooks". The potassium, magnesium and ammonium nutrients have positive charges or "hooks". These hooks hold onto each other and cannot easily be separated. However, when enough force is applied, these nutrients can be removed from the soil particles, just like metal objects can be removed from magnets if enough force is applied. Thus, plants can use the nutrients which they pull off of the soil particles.



K+ -- Potassium
Ca++ -- Calcium
Mg++ -- Magnesium
NH4+ -- Ammonium

Water flowing through the soil does not have enough force to remove the nutrients that are held by the soil particles. Nutrients such as nitrate, phosphate, chloride, and sulphate are all negatively charged, just like the soil particles. (Negatively charged nutrients are called anions.) Two particles with the same charge repell each other. Thus, these nutrients are not held by soil and can be leached out of the soil if enough water passes through. This does not usually happen in clay soils in Manitoba but can happen in sandy soils if a large amount of water flows through the soil in a short

period. For example, a 15 cm rain, if all the water went into a sandy soil, could move these nutrients down 90 to 120 cm. On the other hand, in a clay soil it would only move these nutrients about 60 cm if all the water percolated through the soil with no runoff. Research has shown that clay soils can hold about twice as much water as sandy soils can, so it follows that the nutrients would only be moved half as far.

Generally, a clay soil or a soil high in organic matter is a more fertile soil than a sandy soil. Of course the addition of nutrients as fertilizers makes a sandy soil almost as fertile as a clay soil.

E. Soil Moisture

In Manitoba, soil moisture can be the main limiting factor to crop production, especially in dry years. For the most part, farmers must rely on nature to supply moisture for their crops. Nature often provides enough moisture, but not always at the right times during the growing season to produce maximum yields.

This is where farmers can make gains by learning how to conserve soil moisture. Almost all the available water that falls as rain during the growing season is used by crops. The essence of a good soil moisture conservation program is to capture and make good use of the water that falls as rain or snow when no crops are on the field.

To understand the potential for soil moisture conservation we must first understand the basics of what determines the amount of soil water that is useful to plants.

Plants cannot use all of the water held in the soil. Two physical limits dictate the amount of soil water that is available to plants. The upper limit is called field capacity; the lower limit is the permanent wilting point.

Field Capacity -- This is the maximum amount of water held in a soil, measured a few days after it has been thoroughly soaked and allowed to drain freely. This is the optimum moisture condition for plant growth. Field capacity depends primarily on soil texture. Clays, for example, hold more water than sandy soils, so an increasing clay

content increases the field capacity. From a moisture conservation point of view, if the soil is at field capacity any water from irrigation or rainfall will simply drain through the soil and therefore is of no benefit.

Permanent Wilting Point -- As crops draw water from the soil, it becomes increasingly difficult for them to use the soil water that is left. If plants cannot extract sufficient water to meet their requirements, they begin to wilt. The soil water content at this point is called the permanent wilting point; the point at which water is no longer available to plants.

Available Water -- This is the amount of water held in the soil that the plants can use. The maximum amount of available water held in a soil is the difference between the permanent wilting point and field capacity, expressed in millimeters or inches of water per unit depth of soil.

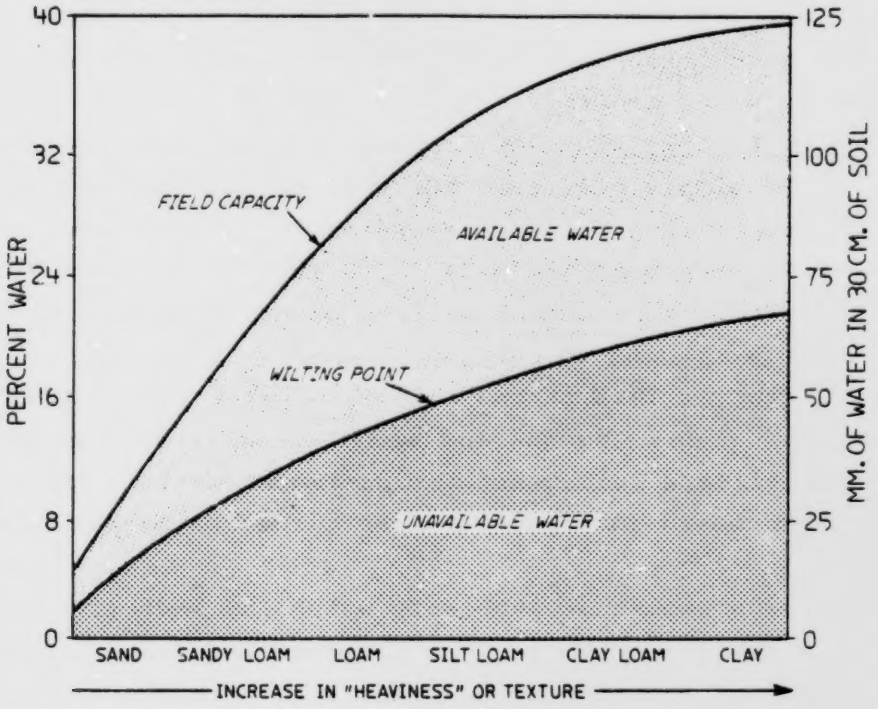
The average amount of available water for several Manitoba soils is shown in the table below. The readings were taken in the normal rooting depth of Manitoba crops. Roots of most annual crops do not penetrate much more than 90 to 120 cm below the soil surface. As can be seen from the table there is a sizeable variation in available water between coarse and fine textured soils. However, the differences between medium, moderately fine and fine textured soils are quite small

AMOUNT OF AVAILABLE WATER IN SOME MANITOBA SOILS

Soil texture	Kind of soil	Available water to 120 cm (mm)
Coarse	Sand, Loamy Sand	145
Moderately Coarse	Loamy Very Fine Sand, Sandy Loam	240
Medium	Very Fine Sandy Clay Loam, Silt Loam, Silt	255
Moderately Fine	Clay Loam, Sandy Clay Loam, Silty Clay Loam	260
Fine	Sandy Clay, Silty Clay, Clay	260

The following graph illustrates the relationship between the Field Capacity, Wilting Point, Available Water and Unavailable Water to soil texture.

Figure 4 Relationship Between the Field Capacity, Wilting Point, Available Water, and Unavailable Water to Soil Texture.



Soils have different abilities to hold and store moisture for plant growth. Water is held in soils in the spaces between soil particles. The more spaces there are, the more water is held. Clay soils have many spaces and are not very large ones. Sandy soils have fewer spaces and they are quite large. These large spaces allow water to percolate through the soil and therefore, is is lost to plants. The small pores of clay soils hold the water and prevent it from percolating through the soil, or slow it down so much that plants can use it before it is gone.

The preceeding graph shows why clay soils usually do better in dry years than sandy soils. Usually most areas and most soils in Manitoba have all the moisture they can hold in spring. This is the result of fall rain and spring snow melting. Thus, there is usually no need to summerfallow to store soil moisture because the soil already has all the moisture it can hold. However, if fallowing is

done for other reasons, (weed control, nutrients, etc.) it is important to keep it free of any growth. Weed growth uses moisture and particularly nutrients, which are needed for the crop next year.

Plants cannot extract all the available water between field capacity and permanent wilting point with equal ease. Obviously, soil water is more readily available to plants when soils are near field capacity and less so as we approach the wilting point.

This "readily available moisture" is the water that is used up before a moisture deficit starts to affect crop yield. For many crops, this represents the top half of the available moisture range between field capacity and wilting point.

Most crops will start to suffer from a lock of water once 25 per cent to 50 per cent of the available water is use up, or long before the soil reaches the wilting point.

Conservation of Soil Water

Various conservation methods can be used to increase the amount of water that is made available to crops. Reduced tillage, increased use of trash or stubble and continuous croppping all help to conserve soil moisture.

Summerfallowing, on the other hand, is a poor method of moisture conservation. The idea behind summerfallow is to keep the weeds down and eliminate plant growth to increase soil moisture reserves for next year's crop. However, some moisture will be lost by runoff and evaporation from the soil surface. Furthermore, the capacity of the soil to hold water is limited; once the capacity is reached any additional moisture will drain through the soil.

The efficiency of summerfallow for saving moisture decreases as we move from west to east, across the prairies, as the average annual rainfall increases. Regardless of the soil type this is an inefficient method of moisture conservation. Even in the drier grassland soil zones as the Brown and Dark Brown zones of Alberta and Saskatchewan, stubble sometimes contains as much moisture as fallow at seeding. In Black Grassland and Gray Wooded zones, fallow does little to increase available spring moisture. These two are the dominant soil types in Manitoba.

Continuous Cropping

An obvious alternative to summerfallow is continuous cropping. With continuous cropping, fields have no crop growth for about nine months through the fall, winter and early spring. With fallow fields bare for 21 months, on average, only 6% to 13% of the rainfall in this period is retained on Manitoba fallow fields.

Generally, continuous cropping is a very efficient way of using soil moisture. As much as 85% to 90% of seasonal precipitation is used by crops under continuous cropping. But this per centage declines as the frequency of summerfallowing increases. Continuous cropping also helps to control saline seep. Excess moisture that would otherwiwe contribute to salinity is used to grow crops. Spring moisture conditions in Manitoba are almost always adequate for continuous cropping.

Moisture losses from soil

Soil moisture is removed or lost from soils in several ways. Some is lost due to normal crop growth and therefore necessary. Some is lost as a result of poor farm practices.

1. Crop Use -- This is the removal of water from soils by growing plants. Some of the water is kept in the plant but most of it is passed through the leaves into the air as a vapor. This is a necessary part of plant growth and there is no way to save this water.
2. Evaporation -- A large amount of water is lost from the soil by evaporation each year. This process usually dries out the upper 10 to 15 cm, or at least to the depth the soil is cultivated. Thus it is important to keep cultivation to a minimum in spring to conserve as much moisture as possible for seed germination.
3. Runoff -- Water is lost for plant use when it runs off the surface before it can infiltrate into the soil. This water usually ends up in sloughs, rivers or lakes. This is particularly a problem on hilly land. Working and seeding the land across the slope helps prevent the water from running off. This allows it to infiltrate into the soil. Trash cover on soil also slows down runoff water and allows it to infiltrate for future use.

Percolation through the soil

Percolation is the movement of water through the spaces between soil particles. This water eventually ends up as ground water. This water is often too far below the surface of the soil to be used by plants. As mentioned earlier, percolation of water through a clay soil is extremely slow because the spaces between particles are so small. Thus most water falling as rain during the growth of a crop is retained in the root zone to be used by the crop. In sandy soils, the water infiltrates rapidly and percolates through the soil faster than in clays. However, it should be remembered that it takes about 15 cm of rain to wet a sandy soil to 120 cm when it is dry. Thus, most rainfall will infiltrate into the soil but will not percolate too far down so that plants can still use the water.

Moisture use by crops

A fertilized crop uses soil moisture to better advantage than a non-fertilized crop. This can be seen from data gained in trials in Manitoba and North Dakota.

Number of Trials conducted	Moisture Supply - Rainfall plus stored to 1.2 m	Average wheat yield kg/ha	
		Non-Fert.	Fert.
7	16.2 cm	1049.8	1426.7
9	21.3 cm	1177.7	1446.95
8	24.1 cm	1393.1	1992.0
9	26.6 cm	1527.7	1992.0
10	30.4 cm	1702.6	2362.2
9	32.7 cm	2052.6	2577.59
10	35.8 cm	1938.2	2624.7
11	40.1 cm	1998.8	2631.4
9	43.4 cm	1783.4	2469.9
9	51.0 cm	1958.4	2745.8

This data shows that a greater yield is obtained for a given moisture supply when the crop is fertilized. The response to

fertilizer was greater where more moisture was available. For example, where only 16.2 cm of moisture is available to the crop, a 376.9 kg increase was obtained by fertilizing. Where 35.8 cm of water was available ot the crop, a 686.5 kg increase was obtained by fertilizing the crop. It should be pointed out, that even where only limited moisture was available, the added returns from applied fertilizer were more than enough to pay for the fertilizing.

Tillage and Crop Residues

Crop residues left on the surface, especially standing stubble, conserves water by decreasing evaporation, retaining snow, reducing runoff and increasing the infiltration of water into the soil. The effect of tillage in conserving soil moisture is directly related to the amount of crop trash left on the surface. This will vary with the implement. Chisel plows, for example, are superior to moldboard plows since they leave about half of the straw on the surface, whereas the moldboard plow buries virtually all residues.

Minimum and No-Till Systems

Reduced tillage systems are effective in conserving soil moisture due to the presence of a trash cover over the soil surface. The crop is seeded into moist soil directly below the trash cover, without destroying the trash.

Research in Manitoba has shown that the no-till system is a very efficient method of conserving soil moisture. No-till straw management requires that the crop residue be evenly spread to allow for uniform production of the seeding equipment. No-till eliminates the need for spring tillage, thereby conserving soil moisture, particularly in the surface 0 to 5 cm layer. Surface soil moisture may be critical for good germination and emergence. Thus zero tillage may be very beneficial in years when soil moisture in spring is low.

STORED WATER IN SOIL AT 5 & 20 CM DEPTH

mm of water stored

	Straw Burned		Straw Removed		Straw Scattered	
Depth	Till	O-till	Till	O-till	Till	O-till
0-5 cm	5.5	10.5	6.0	13.01	4.5	11.0
5-20 cm	36.5	49.5	42.5	54.00	76.5	49.5

Source: Gauer and Shaykewich, 1981

Snow Management

Snowfall accounts for 20 to 30% of our total precipitation. Thus there does exist some potential for increasing soil moisture by retaining snow. Under dry soil conditons 50% of the snowfall can be conserved and stored in the soil. If the soil moisture in the fall is relatively high, then a smaller proportion of the snowfall will be stored. The moisture stored from rainfall can be significant in giving the crop a good start in the spring. However, moisture stored from snow cannot alleviate a drought caused by inadequate rain during the growing season.

There are competitive and non-competitive barriers depending on whether they compete with the crop for moisture. Tree shelterbelts and grass strips are obvious examples of competitive barriers, while snow-fences, man-made snow ridges and trap strips are non-competitive.

Shelterbelts -- Generally, they are most effective, from a moisture point of view, when there is ample snowfall and in situations where fields would otherwise be exposed to winter winds. They are of little benefit when the autumn or spring rains saturated the soil, when snowfall is below average, or when winds are too light to drift the snow.

Most shelterbelts are poorly designed for uniform snow distribution. Large drifts tend to pile up on the lee side, which delays seeding and can contribute to salinity on these field edges. In many cases, shelterbelts would be improved if some trees were removed so they wouldn't cause this "wall effect" on the lee side. Bush, low branches, and tall grass should also be cleaned out.

Grass barriers -- Saskatchewan and Montana research indicates tall wheatgrass is the best species for grass barriers. In these areas wheatgrass barriers increased soil moisture by 40 to 50%, so conventional wheat-fallow rotations could be replaced by continuous cropping. Remember that grass barriers require more management than stubble and they compete with the adjacent crop for moisture. Continuously cropped fields will not benefit greatly from grass barriers.

Snow-fences -- Snow-fences are not practical or economical for dryland agricultural areas.

Windrowing (Snow ridging) -- These are mechanically formed snow ridges. Weather dictates the success of this practice. Consequently, the benefits are inconsistent. Quite often they are economical in terms of expected yield increases.

Stubble -- About half of the winter snowfall can be trapped by stubble if it is managed properly, and about half of that will provide soil moisture for the next crop. Best of all, it doesn't really entail much extra work. There are two ways to use stubble to trap snow: swath crops at different heights or from trap strips. Trap strips are relatively simple to make using clipper or deflector attachments on the swather. These harvest the grain but leave tall narrow strips of stubble on each pass to trap snow, while cutting the rest of the swath at normal height. As much stubble as possible should be left in an upright position. Standing stubble is much more effective at trapping and holding snow than stubble that is lying flat on the ground. Therefore, for maximum benefit, fall tillage should be reduced to a minimum.

II. PROBLEM SOILS

A. Saline Soils

Saline soils are often referred to as "alkali" soils by farmers because of the white crust when it is dry. The term "alkali" does not properly describe a saline soil. A true alkali soil has a poorly structured, impervious layer near the surface and has an excess of sodium. There are no true alkali soils in Manitoba. Salinity in the soil is due to salts that are soluble in water or the liquid part of soil. There are many kinds of salts present in soil. In Manitoba salinity is usually caused by salts such as sodium chloride, sodium sulphate, calcium chloride, magnesium chloride and calcium and magnesium sulphate. These salts all dissolve in water. Lime or calcium carbonate is not very water soluble so it is not a soluble salt and does not contribute to soil salinity.

Saline soils are caused by two main factors:

1. Topography -- Groundwater moves through the soil from elevated upland recharge areas to discharge areas at a lower elevation. When precipitation is greater than the crops can use on the elevated areas some water percolates through the root zone to the water table and enters the groundwater system. As the water moves through the soil toward the lower lying area, salts are dissolved and carried along in the flow. The water tables in these lower discharge areas are generally close to the surface so the capillary forces in the soil carry the salt bearing water up to the surface where the salts accumulate, once the water evaporates or is used by plants. The distance between the recharge and discharge areas can be 30 kilometers or 30 meters. Distance is not a factor. They can be on the same field or townships apart.

Salinity generally occurs in discharge areas where the water table is high, within 1 to 2 meters of the surface, especially in fine textured soils. Sometimes, saline groundwater is present under artesian pressure.

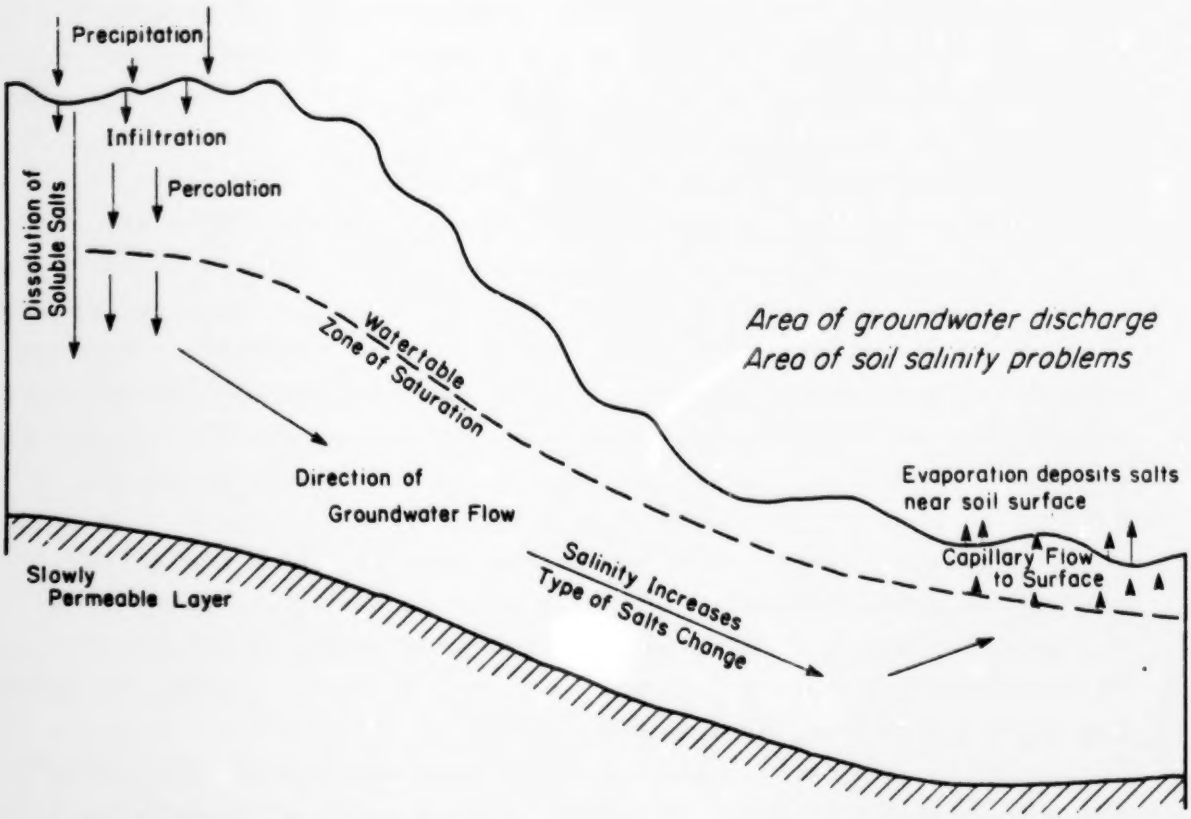
2. Salt Accumulation -- There has to be a source of soluble salt in the groundwater for a salinity problem to occur. Salts may be

present in the parent material or the deeper geologic materials, however, they must accumulate on or near the surface before they can be recognized. The kind and amount of salts in saline soils can be measured by a soil test.

Water and nutrient uptake by plants is reduced on saline soils. Thus, despite the fact that saline soils tend to be moist, their major limitation to plant growth is the fact that the plants cannot absorb sufficient moisture.

Origin of Soil Salinity

Area of groundwater recharge
No salinity problems



1. Recognition of Saline Soils

Saline soils may be recognized in the field by studying the soil and the cultivated crops or native plants. Actual concentrations of salts in the soil can then be determined by chemical and physical analysis of the soil solution.

General appearance of the soil -- In saline areas a surface crusting of a greyish or white powder-like substance may occur. Close inspection of the upper portion of the soil profile usually reveals either greyish and whitish clusters of gypsum crystals about the size of pin heads or a network of white thread-like formations filling old root channels in the soil. If none of these conditions are present, it does not follow that the soil is free of salt. Many of the soils in Manitoba have a uniformly whitish coloration on the surface and throughout the profile. These soils are usually high in lime and not necessarily saline.

Condition of plants growing on saline soils -- Barren spots and stunted plants may appear in cereal or forage crops growing on saline area. The extent and frequency of the bare spots may be taken as an indication of the concentration of salts in the soil. If the level of salinity is not sufficiently high to result in barren spots, the major characteristic in the appearance of the crop may be a marked irregularity in vegetative vigor.

Some crops develop abnormal leaf conditions when grown on saline areas. Cereal leaves develop tip burn and firing along their margins. This condition usually begins at the two-leaf stage and becomes progressively more severe as the plant grows. The plants become stunted, lower leaves wither, and if the salinity is severe, the whole plant may die.

Salt-tolerant crops like sugar beets and some of the grasses show deep blue-green colored foliage. This condition is usually accompanied by sparse and irregular crop stands.

Measuring degrees of salinity through soil tests -- The electrical conductance of the extract from a water saturated soil sample is used to determine the degree of salinity of the soil. It is usually expressed in millimhos per centimeter. (A mho is the opposite of an ohm, and expresses conductance.) The relationship between the salt concentration in the soil extract and its effect on plant growth is shown on the next page.

Electrical Conductance (E.C.) - Millimhos per Centimeter	Plant Response
0 - 2	Salinity effects negligible
2 - 4	Yield of sensitive crops may be resticted
4 - 8	Yield of many crops restricted
8 - 16	Only a few tolerant crops yield satisfactorily

To measure soil salinity, samples must be taken at 0 -15 cm and 15 to 60 cm. These samples should be sent to the Provincial Soil Testing Lab.

2. The effect of soluble salts on plants

Salts interfere with the ability of the plant to take up water from the soil. The plants suffer from drought even though the soil may appear to contain sufficient moisture for good crop growth. In order to absorb water, the plants must overcome the salt effect. Hence, as the salt concentration increases, it becomes increasingly difficult for plants to absorb water. As long as plants are small and require little water the effects of salinity are not very noticeable. However, with increasing growth and water requirements, plants find it difficult to secure enough water and hence show typical drought symptoms.

Plants growing on saline soils absorb a certain amount of the salts. If the plant takes up an excess amount of some salts they become toxic to the plant. Salts may also inhibit the uptake of other essential nutrients and cause unthrifty conditions in crops growing on these soils.

3. Movement of salt in soils

Soluble salts are transported by water. Soluble salts increase or decrease in the root zone, depending on whether the net movement of water is downward or upward. The downward movement of water through the soil causes the salts to move away from the root zone

(leaching). The accumulation of salt in the root zone is caused by either an upward rise of water (capillary rise) from a high water table or an inflow of foreign, salt carrying, water (seepage) and the subsequent evaporation of the water. There must be a net downward movement of water to keep the root zone free of salt.

The rate of downward movement of water is affected by the texture, structure, and porosity of the soil. Drainage through the various soil layers is enhanced by granular structure, medium to coarse texture and high porosity.

As long as the conditions are right for proper internal drainage, salinization of the soil will not occur.

Poor internal drainage occurs in soil layers which have a heavy texture and a low porosity. Many saline areas have an underground water table close to the surface because of these factors. Water enters the surface of the soil at a rate in excess of the movement of water through the heavy-textured subsoil. Very little of the water drains away through the subsoil and most of the water must be disposed of through surface evaporation and transpiration by plants. When the water evaporates or is taken up by the plant, the salts which are present in the soil solution are left at the surface or in the root zone of the soils causing the formation of the saline soil.

4. Management of saline soils

There are no quick or easy solutions to soil salinity. Saline soils can only be reclaimed by rinsing the salts down and out of the root zone. This involves adopting water management practices which improve drainage and promote the downward movement of salts in the saline soil. Management practices are likely to be more successful on weak to moderately saline soils. Strongly saline soils should be seeded to salt tolerant forages and grasses and managed as permanent grassland.

If real progress is to be made, one must be patient, persistant and plan ahead. In dry years, the crops may suffer more from salinity because the salts make it more difficult for the plants to absorb the limitied amount of water that is in the soil.

Paradoxically, because the soil is dry, the limited rainfall is more effective at leaching salts down in the soil profile in dry periods.

In wet periods, crops do relatively well, but because the water tables are high the salts may be returned to the surface.

The basic objectives of any program to control salinity are:

-- use the water where it enters the soil
-- improve drainage on flat or low lying areas
-- promote the downward movement of water in salt affected soils.

There are basically 11 steps which can be taken to reclaim the productivity of salt affected soils.

1. Soil Test -- Before any major decisions are made determine the severity and type of salinity.

2. Improve Drainage -- Eliminate prolonged surface ponding and maintain the water table at a level which keeps saline water below the root zone. There are several ways to do this. Growing deep rooted forages such as alfalfa and clover is probably the easiest and most economical method. Installing open ditch drains will remove surface water and maintain lower water levels. If done properly, drainage is an effective control measure. The ultimate goal is to leach the salts out of the rooting zone of the soil. This is a long and slow process under dryland farming conditions.

3. Reduce Summerfallow -- Summerfallow conserves some soil moisture but not very efficiently. A significant amount of the precipitation on summerfallow is lost to the groundwater supply. This unwanted addition to the ground water in the recharge area can be reduced somewhat by continuous cropping. The rotations should include some deep rooted perennial forages. The cultivation of summerfallow also causes moisture to evaporate, leaving more salts at the surface of the soil.

4. Select Salt Tolerant Crops -- Different crops have different tolerances to salinity. A list of crops indicating their relative tolerance levels to salinity is shown on the next page. These crops can be expected to yield at least 50% of the normal yield at the indicated levels. Perennial forages will generally use more water

than cereal crops. Thus they reduce the soil's total water volume and increase the likelihood of salts being washed down in the soil by rain water.

RELATIVE SALT TOLERANCE OF MANITOBA CROPS

Tolerance increases as numbers increase mS/cm.

	Forage Crops	Field Crops	Vegetable Crops
1			
2	Red Clover Alsike Red Top White Dutch Timothy	Corn Soybeans Field beans Peas Sunflowers	Sweet corn Green beans Celery Radishes
3			
4			Cucumber Peas Onion Carrot Potatoes
5			
6	Reed Canary Meadow Fescue Intermediate Wheat Crested Wheat Bromegrass Alfalfa Sweetclover	Rapeseed Wheat Flax Rye Oats Barley* Sugar beets	Spinach Asparagus Garden beets
7			
8			
9			
10			
11			
12	Russian wild rye Slender wheatgrass Tall wheatgrass	Occasionally the more tolerant field crops yield well. However, this land is best suited to producing salt-tolerant forage crops for hay.	
13			
14			
15			
16	Few if any agricultural crops do well. Try tall and slender wheatgrass.		

NOTE: The numbers indicate the range of salinity at which crops within the tolerance group can be expected to yield at least 50% of normal yield.

5. Seed High Moisture Crops -- Continuous cropping is more successful in preventing excess moisture buildup in the recharge area when high moisture use crops such as perennial forages are included in the rotation. Growing alfalfa in a recharge area, for example, could reduce the water table by 3 to 4.5 meters in a few years.

6. Use Manure and Crop Residues -- Manuring at a rate of 40 to 60 tonnes/ha once every three to four years on saline areas is often beneficial because it improves the infiltration, water holding capacity and tilth of the soil. Working straw back into the soil also reduces run off and promotes infiltration of water into the profile.

7. Avoid Deep Tillage -- Eliminate tillage of saline soils altogether, if possible. Over the growing season the upper few cm of the soil may be leached free of salts by rainfall. Deep tillage only brings these leached salts back to the surface. Zero-till practices should be considered for strongly saline soils. Deep plowing is definitely not recommended for saline soils.

8. Seed Shallow --Seed close to the surface and as early as possible in the spring. Salts dissolved in soil solutions are generally more diluted in the spring and the seeds are able to germinate and root under the good moisture conditions. Dry soil and high temperatures tend to increase salt injury to young seedlings.

9. Use Recommended Fertilizers -- Fertilizer will not correct salinity but it may increase crop yield. Phosphate fertilizers stimulate root growth at seeding so the plant becomes better established and utilizes more available moisture. No chemicals or commercial soil conditioners will cure soil salinity. The addition of lime, sulphur or gypsum is of no value because our saline soils already contain large quantities of these products.

10. Use Interceptor Crops -- On sloping land interceptor crops intercept water that would otherwise flow down through the soil and contribute to the salinity problem in the discharge area. Interceptor crops are deep rooted forages that are planted toward the bottom of the slope between the recharge and discharge areas.

11. Reduce Weed Competition -- If weeds are controlled, seeded crops and forages have a better chance to establish.

One of the major limitations to implementing a comprehensive program to control salinity is that the recharge area and the discharge area are often not under the control of the same farmer. In these cases, control measures can only be applied to the affected areas rather than attacking the source of the problem, unless the two producers co-operated to control the problem.

B. Poorly Drained Soils

One of the major problems on clay soils is poor surface drainage. The reason for this is that clay soils tend to hold water

on the surface because of slow infiltration of water and because they are usually very flat. Thus in order to insure that crops will not drown because of water standing in the crop too long, a good system of surface drains is a must on clay soils. The farmer must work along with his municipal government since any water drained off his fields must be drained into municipal ditches.

Proper surface drainage is a must to insure that crops will not drown after a heavy rain. There is no point in investing in good seed, weed sprays, fertilizer and so on if the chances of the crop being drowned because of poor surface drainage is high.

C. High Lime Soils

Soils high in calcium carbonate (lime) are called high lime soils. These soils usually have only a very shallow layer of black soil of "A" horizon over parent material which is very high in calcium carbonate.

There are several problems that are common on these soils.

1. They are usually extremely deficient in phosphorus. The parent material is very low in phosphorus content so the naturally occuring plant available phosphorus is very low. For this reason, these soils usually require more phosphate fertilizer than many other soil. A soil test is the best way to determine what the fertilizer requirement is for a particular field and crop.
2. High lime soils appear to be more droughty than most other soils. This seems to be because these soils do not hold as much water as other soils with the same texture.

Generally, crops can be grown very successfully on these soils when good management practices are followed.

D. Soil Erosion Problems

The removal of soil by wind and water from the surface of soils is known as erosion. Soil erosion by wind occurred on the prairies of Western Canada soon after the land was brought under cultivation. Water erosion is usually not as spectacular as wind erosion but it can result in great damages. Both types of erosion are going on

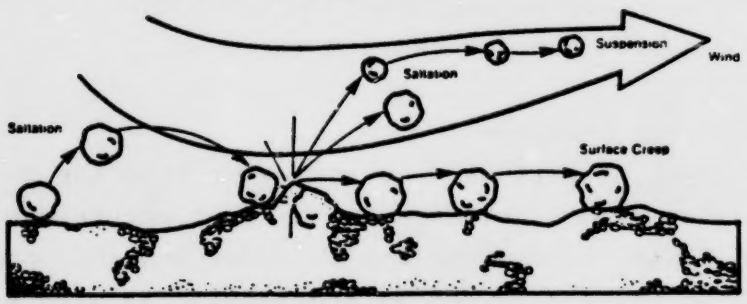
continuously to a greater or lesser extent. From management practices, topography and climate all influence the amount of erosion that takes place on an individual field.

1. Erosion By Wind

Soil erosion by wind is usually associated with the practice of summerfallowing, but it is not necessarily confined to fallowed fields. It can occur during the spring when land is not protected by young crops.

Soil drifting is caused by wind blowing more than 20 km/h across an unprotected soil surface that is dry, loose, and finely granulated. Dust particles less than 0.1 millimeter in diameter, once dislodged, are lifted into the air and carried in suspension for many kilometers. This accounts for about 5% of our erosion problem. Coarser particles (about 0.1 to 0.5 millimeters) are lifted upward a distance and then travel forward and downward at high speed. They strike the soil surface, breaking down clods and surface crusts and dislodging other particles. This is called saltation and 50 to 75% of our erosion happens in this way. Larger particles (about 0.5 to 1.5 millimeters) creep and roll along the surface. This is called surface creep. Winds of extremely high velocity may move particles larger than 1.5 mm but those 0.5 mm and less are the most erodible.

Saltation Initiates Movement of Other Soil Particles in Suspension, Saltation, and Surface Creep.



Drifting usually starts on exposed knolls in the field, tracks in which implement wheels have crushed clods, and corners of fields that have been excessively cultivated. The abrasive action of soil blown from these points soon changes a resistant surface to one that may drift.

Damage -- Damage caused by the wind erosion of soil takes many forms. Drifting over a period of years depletes fertility. This is demonstrated by the fact that the fine dust particles moved from a field contain up to twice as much nitrogen, organic matter, and phosphorus as the material remaining.

Drifting also results in a gradual change in the texture of the cultivated layer. Studies conducted in Western Canada revealed that the sorting action of the drifting process removed up to one half of the silt and third of the clay from some soils. Losses of about one fifth of the silt and smaller quantities of clay particles were measured on severely eroded medium-textured soils. Heavy clay soils were least affected by sorting action. Reduced moisture-holding capacity of the cultivated layer resulted from the loss of the silt and clay particles, and the soil was more easily eroded.

The removal of drift soil from a fence line, a roadside drainage channel, an irrigation ditch, or around farm buildings is costly, Drift soil deposited in farmstead shelterbelts can ruin the plantings, which may take years to replace. Crops can be blown out completely or the yield reduced by the sandblast effect of drift soil. Reseeding is expensive and yields may be reduced.

Factors that influence erosion -- The following factors influence the beginning, extent, and eventual control of soil drifting.

a) Wind - the hazard of soil erosion by wind increases as wind velocity increases. High velocity winds that blow for several hours or intermittently for several days are the most frequent cause of drifting.

b) Soil Moisture - moist surface soil does not drift. Tillage may expose moist soil, which if pulverized, resists drifting only until it dries out. Moisture from rain or snow that thoroughly soaks the surface, consolidated the soil. Except on drift sand, a crust is

usually formed as the surface dries, and this crust prevents drifting until it is broken. A small amount of moisture does not consolidate and crust the soil surface, hence drifting is stopped only until the surface dries out.

c) Cloddy Surface -- A field on which at least half of the surface clods are larger than 1.0 mm resists most strong winds. A field that contains two thirds or more of the erodible granules (less than 1.0 mm) on the surface is eroded by a light wind. Clods are broken down ty tillage, by crushing under implement wheels, by abrasion, and by weathering.

Soil texture influences the resistance of clods to breakdown in size. Fine sand and fine sandy loam soils form clods only when cultivated while moist and firm. Such clods are readily broken down by heavy rainfall and by drying while frozen. Loam, silt loam, clay loam and silty clay loam soils form clods when tilled. These clods are more resistant to breakdown than clay or sandy clods. Measurements of clod breakdown by weathering during the winter indicate that on all but the most resistant soils the freeze-drying and other weathering processes can change a resistant soil surface to one that is highly erodible. The change in erodibility over winter is dependent upon soil type, weather conditions and soil crusting.

d) Vegetative Cover -- Plant residue, or trash cover, and growing crops protect soil from wind. The degree of protection depends on the quantity and type of cover.

e) Field Size -- The larger the field, the greater the hazard of soil drifting.

f) Topography and Wind Barriers -- Erosion usually starts on unprotected knolls. Wind barriers such as field shelterbelts reduce the hazard of soil erosion.

Controlling Wind Erosion

There are four principles of wind erosion control:

1. Establish and maintain vegetation or vegetative residues to protect the soil.

2. Roughen the land surface to reduce wind velocity and trap drifting soils.
3. Create or bring to the surface aggregates or clods large enough to resist the wind.
4. Reduce the unsheltered distance along the prevailing wind by establishing wind barriers at designated intervals to reduce the wind velocity and soil avalanching.

Crop Residues -- are the single most effective and practical means of controlling wind erosion. A field that produced wheat would need about 2.7 tonnes of wheat straw per hectare in order to protect it adequately for the winter.

The amount of straw or stalks required to do the job depends upon the erodibility of the soil. The more prone a soil is to wind erosion the more crop residue is required to protect it. Since erodibility decreases as you move from sand to clay, so does the straw requirement for all crops.

The type of residue is also important in controlling wind erosion. Different crops porduce different types of straw. Straw position also has a bearing. For example, it takes 1.6 times more flat corn stalks to protect a field than it does if the stalks are standing. Naturally, the volume of straw a crop produces is based on the yield.

Tillage is one farming practice that has a direct influence on the amount of crop residue that is left on the surface to combat erosion in the spring. Each pass with a tillage implement buries some of the trash and weakens its effectivenesss. So for maximum erosion control tillage operations should be kept to a minimum.

All the crops grown in Manitoba produce enough residues with obtainable yields to prevent erosion. The real question is, "Is enough trash left on the surface to check erosion once these fields are tilled?" Peas, beans, lentils, sugar beets and potatoes do not. Unfortunately most of these crops are grown on the more erodible soil types in the province. In these cases secondary conservation measures such as wind barriers, and cover crops are required to reduce wind erosion.

Field Size -- When crops like peas, beans, lentils, sugar beets and potatoes which produce little trash are grown on very erodible soils the fields should be kept small in size, preferably no more than 16 hectares. Ideally these fields should be long and narrow and positioned at right angles to the prevailing wind.

Cover Crops -- These are forages and small grains that are seeded on summerfallow to control wind erosion when the soil would otherwise be unprotected. The seeding rates and dates for the most popular cover crops are found in the the Field Crop Recommendations booklet.

Cover crops are usually planted as solid seedings, however, strip seeding may be attempted on all soils except for the most erodible types. Depending on what types of soil you have to work with, leave wider spaces between strips for the less erodible soils. At cover crop seeding rates fall rye should be tilled down in the folowing spring. However, if the crop is to be harvested in spring it should be seeded at double the cover crop rate.

Wind Barriers -- Trees or tall grasses make effective wind barriers. Shelterbelts check wind erosion by cutting down the wind velocity so there is less soil movement. They also reduce field length and consequently soil avalanching. Shelterbelts reduce wind speeds downwind by as much as 50% for a distance equal to 10 times the height of the belt and about 20% for a distance equal to 20 times belt height. The degree of erosion protection depends on the height and density of the belt and the velocity and direction of the wind.

A single row of trees properly spaced and used in combination with other soil conservation practices will protect even highly erodible soils from wind erosion. Green ash trees, for example, should be spaced 2 to 2.5 meters apart. Shelterbelts can also improve the microclimate around the crop and increase the snow catch which in turn may increase the crop yield. To be most effective, shelterbelts should be planted perpendicular to the prevailing winds for the month of May.

Annual crops used as wind barriers should be planted perpendicular to the prevailing May winds to reduce wind erosion on summerfallow or seeded fields after erosion susceptible crops are

harvested. Properly spaced annual barriers also trap snow and povide an effective winter cover. Flax, corn, sunflowers and mustard make good annual barriers. The proper width and distance between the barriers for each of these crops is shown on the table below. The seeding rates are the same as if the crops were planted for harvest.

Crop	Width metres	(feet)	Barrier Spacing metres	(feet)	Seeding Date
Flax	0.3 - 1.2	(1' - 4')	11	(35)	by August 1
Corn Sunflower	1.5 - 3.5	(5' - 12')	18	(60)	normal seeding date
Mustard	0.6 - 1.2	(2' - 4')	8	(25)	by August 1

The perennial, tall wheatgrass can also be used as a permanent barrier to control wind erosion on cropland. This practice has the greatest potential for use on sandy soils, where wind erosion can be a major problem and on summerfallow. On sandy soils the grass barriers are planted in sets -- 2 rows spaced 40 to 270 cm apart with each set spaced 9 to 15 meters apart perpendicular to the prevailing May winds. On less erodible soils the sets may be spaced up to 18 meters apart. The recommended seeding rate is 11 kg/ha. Spring and fall seeding dates are around May 15 and August 1.

Emergency Tillage -- Emergency tillage is a good method of reducing wind erosion potential when there is no cover crop and no straw on the field. It is a short term measure used to quickly check soil drifting and prevent the spread of erosion. It is done by using implements that produce a rough cloddy soil surface.

Crop Rotations -- Rotations are useful in Manitoba to reduce moisture loss, control soil erosion, soil borne diseases, weeds, insects and help maintain soil productivity.

Continuous cropping rotations are ideal in terms of reducing wind erosion for they eliminate summerfallow. Small grain rotations are best since the surface is covered by either standing crop or straw.

The use of erosion susceptible crops in continuous rotations, however, can leave the soil as exposed to erosion as if it were summerfallowed. In these situations, a light trash crop, sush as peas or beans should be rotated with heavy straw producing cereals. In this rotation the cereal straw provides cover for the soil over the winter plus it give some carryover protection to the soil the following year when the peas or beans are grown.

If the rotation contains a number of erosion susceptible crops it would be necessary to use secondary conservation measures, such as shelterbelts, annual barriers, reduced field size and cover crops to reduce wind erosion.

Grasses and legumes in the rotation provide another benefit besides erosion control in that they help keep the soil in good physical condition and replace some of the lost organic matter. These grass crops improve light sandy textured soils so they retain more water and loosen heavier loam and clay soils so they absorb more water, pond less and are easier to cultivate.

2. Water Erosion

Soil erosion by water is influenced by a combination of things. These include rain and snowfall, type or conditon of the soil, topography and type of plant cover.

a) Rainfall -- the most serious soil erosion from rainfall takes place when a large part of the rainfall falls in a short, heavy downpour. Runoff usually is higher if the downpour occurred after long periods of dry weather.

b) Snowfall -- Large amounts of snow in winter usually means a large amount of snowmelt in spring. When a rapid thaw occurs, the resulting melt water cannot be absorbed fast enough by the soil, resulting in runoff causing erosion.

c) Topography -- The steeper the slopes of hilly land, the greater the amount of water runoff. The length of the slope also is important. Long slopes produce more runoff, and approximately 1.5 times the amount of erosion if the length is doubled. The water runs faster and thus causes more soil erosion. Cultivation up and down

slopes encourages erosion, particulary the formation of small gullies. Soil left bare on slopes is very susceptible to erosion.

Effect of Soil Erosion -- When erosion takes place, the lost soil is usually the most fertile surface soil. This leads to reduced yields and usually higher fertilizer costs to replace lost nutrients. Loss of topsoil usually also reduces the amount of water the soil can hold. It also reduces the amount of water that infiltrates into the soil, thus more water is lost due to runoff.

Types of Soil Erosion by Water -- Soil erosion by water may be grouped into three categories: a) splash erosion, b) erosion by surface flow, and c) erosion by channelized flow (gullies).

a) Splash Erosion -- A raindrop falls with a speed of about 9 meters per second (32 km/hr). When these raindrops strike bare soil, they beat the soil into flowing mud which splashes as much as 60 cm high and 150 cm away. During a heavy rain, soil aggregates or clods are disrupted, splashed and shifted about and packed more closely together, and the muddy water plugs the pores on the soil surface. The result is a sealed surface. When this dries, it forms a crust through which air and water can only pass very slowly. Thus water that would have moved downward during a rain must now flow over the surface, carrying soil particles along.

b) Surface Flow -- Water moving across a soil surface moves soil particles along with it by dragging the particles along or carrying them in suspension. In any case, the result is large amounts of surface soil being moved with the water. Examples of surface runoff erosion can be seen on most soils of Manitoba, especially on the knolls of hills in south-central, western and north-western Manitoba.

c) Channelized Flow -- As water moves over the soil surface, some of it concentrates in low places to form channels. Continued flow develops small channels called "rills". These "rills" develop into large gullies as more and more water is channelled through the rills. Examples of gully erosion can be seen in most hilly land, particularly in the Bruxelles area of Manitoba.

Control of Soil Erosion by Water

Anything that reduces the flow of water and its speed over the soil surface or reduces the effect of raindrop splashing, helps to decrease soil erosion by water.

There are three goals to water erosion control:

a) Reduce the impact of raindrops on the soil.

b) Reduce the volume and velocity of runoff water.

c) Increase the soil's resistance to erosion.

Crop Residues

Harvested crop residue is the most powerful tool available for reducing runoff and erosion. The straw or stalks acts like an umbrella. They weaken the pounding of the raindrops, and they form small barriers on the surface slowing runoff. Sufficient amounts spread uniformly on the surface, won't let the rain break down soil clods and carry soil away. Residues also work against sealing and crusting, so the soil can absorb more rain when it falls.

The amount of surface that is covered by crop trash and the roughness of the ground, in early spring and late fall when the danger is highest, are the most important factors in fighting water erosion. Research has shown that it takes approximately half as much cereal straw as corn stalks to obtain the same ground cover. In situations where equal amounts of straw and corn stalks or stover exist, fields covered with cereal straw are better protected, as more of the surface is covered.

Naturally the amount of straw, stover or other crop residue that is left to combat water erosion depends on how much it has been tilled. Research has shown that the greatest soil losses occur when the land is plowed and then reworked with a second tillage operation. Secondary tillage often leaves the soil surface in a very erodible condition.

The absolute losses may vary from place to place and one soil to another, but the fact remains that every tillage operation reduces the amount of crop residue on the surface and exposes the soil that much more to erosion.

Fields with 50% surface cover, for example, reduce the soil loss to about 32% of what it would be on a bare field; 80% cover bring the loss down to about 13% of the bare field.

The erosion reducing benefits of crop residues and minimum tillage are most important when there is no crop canopy on the field to protect the soil from raindrops.

The critical erosion period in Manitoba is between May and June, when most crops are still too short to provide much protection. Conservation or minimum tillage leaves some crop residue on the fields at this time, resulting in less erosion.

Crop Selection

On sloping agricultural land the type and rotation of crops becomes an important control measure. Row crops usually produce the least protection against erosion. Cereal crops give better protection because the plants grow fast and close together. Forage crops produce still thicker cover and provide excellent erosion control. Natural vegetation normally provides enough cover to control erosion.

Contour Strip Cropping

The practice of growing alternationg strips of annual crops and forages across the contour of a hill is referred to as contour strip cropping.

For maximum water erosion control the strips should be arranged roughly at right angles to the slope. Contour strip cropping is best when the slopes are long and not very steep, say 6% or less. It's not very practical on rolling countryside when the slope can change drastically from one hill to the next.

REDUCTION IN SOIL LOSSES COMPARED TO UP-DOWN SLOPE CROPPING

	% Reduction
Across the Slope	25
On the Contour	50
Strip Cropping Across the Slope	60
Strip cropping on the Contour	70

Tilling and planting crops across, rather than down a slope can reduce soil losses by 25%. Where practical, tilling and planting on the contour can cut the soil loss in half. Strip cropping across the slope reduces it by 60% and contour strip cropping by 70%.

Grassed Waterways

Grassed waterways can be seeded to grasses or legumes. They should have a shallow grade so the water is moved off the field and slowly down any slopes. The grass slows the water down so it doesn't erode the bank. Grassed waterways are generally used in areas where gully erosion is a problem to get water off the fields without causing erosion.

III. SOIL TESTING IN MANITOBA

Introduction

The Manitoba Soil Testing Laboratory was established in 1963 to provide a soil testing service for Manitoba crop producers. Laboratory test procedures have been developed for Manitoba's soils, climate and crop conditions.

Fertilizer recommendation guidelines have been calibrated on the basis of field and laboratory experiments conducted throughout Manitoba. Actual crop response patterns to fertilizer nutrient applications have been measured using Manitoba crop varieties. Fertilizer recommendations are reviewed annually and changed if necessary. As more information is gained about the nutrient requirements and response patterns of various crops and the behaviour of fertilizer materials in soils, it is incorporated into the recommendations.

A reliable soil test gives an inventory of the plant available nutrients and other chemical factors important for crop production. This inventory is a basis for recommending additional nutrients when required. The amounts and kinds of nutrients suggested depend on the crop to be grown, and the target yield goal in addition to nutrients already in the soil.

Soil testing results do not offer a basis for determining land values nor can they provide explanation for poor yields caused by factors other than available soil nutrient levels or certain inherent soil properties. Tests do not consider the effect of weather conditons, diseases, insects, weeds and poor management. The laboratory cannot guarantee the degree of crop response attainable from its recommendations under all management and environmental conditions since production can be limited by many factors. Recommendations on the types of crops to be grown are not made.

Routine Soil Testing Services

Two types of routine packages are available:

1. Complete Test
   -- considered the best test for all cropping situations
   --analysis include nitrogen, phosphorus, potassium and sulphur measurements
   --soil texture, pH, salinity and carbonate content are determined
   --provides recommendations for nitrogen, phosphate, potash and sulphur as required
   --Target Yield recommendations for wheat, oats, barley, flax, canola and grain and silage corn and sunflowers are made
   --representative soil samples required from the 0-15 cm (0-6 in) and 15-60 cm (6-24 in) depth
2. Single Depth (topsoil) Test
   --useful only for lawns, gardens, pastures or established forage stands where adequate quantities of sulphur are known to be available
   --analyses include measures of available soil nitrogen, phosphorus, potassium, texture, pH, salinity and carbonate content
   --provides recommendations for nitrogen, phosphate and potash as required
   --soil samples from the 0-15 cm (o-6 in) are necessary

Optional Testing Services

Four standard options are available with a routine so81 test. These include:

1. Organic Matter Test
   --gives the % organic matter content of the 0-15 cm (0-6 in) sample
2. Secondary Nutrient Test
   --indicates the level of exhangeable calcium and magnesium of the 0-15 cm sample
3. Micronutrient Test
   --provides a measure of the extractible levels of copper, zinc, iron and manganese in the 0-15 cm sample

--interpretive comment and suggestions for micronutrient applications given if a potential problem is detected

4. Boron Test

--provides a measure of the extractible boron level

--interpretive comments and recommendations given if a potential problem is detected

Special Testing Services

Upon request a variety of soil analyses are available to meet specific needs. These include sodium adsorption ration (S.A.R.), detailed salinity, cation exchange capacity (C.E.C.), mechanical (detailed texture) analyses, etc.

Fee Schedule

A fee schedule is maintained for all services available from the Soil Testing Laboratory. Payment should accompany soil samples. Consult the reverse of an up-to-date information sheet (that accompanies samples sent to the laboratory) or contact your agricultural representative or the laboratory directly for details.

Establishing a Soil Testing Program

Variations in soil nutrient levels particularly nitrogen and sulphur occur from year to year and may also vary within fields even on fields which appear uniform. Because of this, it is important to follow these steps and develop a sound on going fertility program:

--Every field under annual crop production or in the year of establishment of a perennial forage should be given a Copmplete Test yearly to obtain fertilizer recommendations for the four major nutrients.

--Perform the Single Sample Test annually for fieds of established forages where it is known that sulpur is in adequate supply.

--Occasionally, if the situation warrants, an organic matter and/or micronutrient test may be performed. These values will change only very little over a few years.

Soil Sampling

Reliable fertilizer recommendations can be made only if the samples submitted are fully representative of the field or area from where they were taken. Producers must ensure that proper sampling and sample handling procedures are followed; otherwise, invalid recommendations may result. FERTILIZER RECOMMENDATIONS ARE ONLY AS GOOD AS THE QUALITY OF YOUR SAMPLES!

Correct procedures include:

--using proper equipment and supplies

--sampling at the proper time of year

--obtaining samples from correct soil depths

--taking samples fully representative of average field conditions

--immediate and complete air drying under clean conditions

Equipment and Supplies

A soil sampling auger or probe is best for taking samples to the 60 cm (24 in) sampling depth. Shovels and post hole augers are not recommended. Tools may be borrowed from a fertilizer dealer, your local agricultural office of may be purchased directly from the lab. Many fertilizer dealers and some independant custom soil samplers are equipped to soil sample fields using power hydraulic samplers.

Use two clean, labelled pails for collecting samples. Metal pails should not be used if micronutrient testing is being requested. Information sheets, sample cartons, and shipping boxes obtainable from agricultural representatives or the lab are also required.

Time of Sampling

Ideally, samples should be taken just prior to seeding. From a practical standpoint however, this is difficult because producers have little time to plan a fertilizer program and obtain required fertilizer in time for seeding.

Fortunately, it is possible to obtain reliable fertilizer recommendations from samples taken in the fall once soil activity has ceased. By sampling in the fall, there is sufficient time to properly process samples, provide test results and recommendations

and develop a spring fertilizer program. Fall sampling also assists fall fertilizer application.

These guidelines should be followed regarding the sample timing:

--Annual spring seeded crops and forage crops (pre-establishment)
-- in the fall after the surface soil temperature drops to 5 degrees (around September 15) or in the spring.

--Fall seeded crops -- after July 15 or as near (2 to 3 weeks) to seeding time as possible.

--Established forage stands -- any time after harvest.

Representative Field Samples

Soil sampling is done on an individual field basis. Samples from different fields should not be mixed. Begin by evaluating the field to determine representative areas and proceed to sample. Level fields are easy to sample . On hilly filds with knolls, slopes or depressions, take samples from mid-slope positions to get "average" results and to ensure any potential sulphur problem is detected.

Major areas within fields having distinctly different soil properties such as texture should be sampled and fertilized as separate fields because of differences in nutrient requirements that will occur.

Problem areas such as saline spots, poorly drained potholes, and eroded knolls should not be samples unless they represent a significant portion of the field. If they do, obtain separate samples.

All abnormall areas such as old manure piles, burnpiles, haystacks, corals, fencerows, or farmsteads should also be avoided as well as locations of past chemical or fertilizer spills. Samples should not be taken along headlands, within 15 meters (50 ft) of field borders, or shelterbelts or within 45 meters (150 ft) of built up roads.

At least 15 to 20 sampling sites are required for each field to give a good representative sample. A minimum of one sampling site for every 1 to 1/2 hectares is required. Samples taken from only four or five sites in a field are not representative and may result in incorrect fertilizer recommendations.

Correct Sampling Depths

Soil samples must be taken to the full 60 cm depth. Keep 0-15 cm sample material separate from the 15-50 cm depth sample. Phosphorus and potassium recommendations are based on a measure of the amounts of available forms of each of these nutrients contained in the 0-15 cm depth sample. Recommendations for nitrogen and sulphur are based on the measure of the amount of nitrate and sulfate contained in both samples.

Samples taken from the 0-15 cm depth do not give a complete indication of the amount of N and S available to crops. N and S recommendations based on 0-15 cm depth samples usually suggest a higher than necessary fertilizer application rate.

Handling Field Samples

Two composite samples are obtained from each field, one from all the 0-15 cm samples and one from the 15-60 cm depth samples.

Immediately after the samples have been taken, follow these steps:

--Mix the soil in each container thoroughly.

--Remove about 0.5 litre of soil and spread on a piece of clean paper.

--Completely dry at a temperature of not more than 30 degrees C. Do not dry in an oven at a high temprature since this can change the phosphorus, potassium, and sulphur levels.

--Care should be taken to avoid contamination of the samples with foreign materials such as commercial fertilizer, manure, salt, baking soda, water, dust, etc.

--A fan may be used to ensure constant air flow over samples and enhance drying.

Once the sample is thoroughly dry, fill the soil sample cartons. Label each carton with the correct field number and sample depth. Complete and information sheet for each field, and mail the samples to the Soil Testing Laboratory.

Fertilizer Recommendations

Recommdations are based on the results of the laboratory analyses and on the nutrient requirements and response potential of the crop to be grown.

Standard Soil Test Fertilizer Recommendations

Such recommendations are provided for all Manitoba grown crops. A single application rate for each nutrient evaluated in the test is suggested. Recommendations on time and method of application are also included. Under favorable conditions, these rates should provide a good economic return from fertilizer if they are followed.

Target Yield Fertilizer Recommendations

These recommendations are made for wheat, oats, barley, canola, flax, corn and sunflower production. They give an indication of the amount of fertlizer nutrients required by crops (in addition to the amount supplied by the soil) at various production levels.

The recommendations are not intended as yield predictions nor do they imply a guaranteed yield. Rather, they only ensure an adequate supply of plant nutrients to meet specified levels of production. Other factors related to management and plant environment can restrict crop yield potential. These include fertlizer application timing and technique, crop variety, seeding date, seedbed preparation, etc. Target yield goals can be achieved only when all conditions are favorable.

Moisture Modified Fertilizer Recommendations

All recommendations provided by the Manitoba Soil Testing Laboratory are designed for "average" Manitoba conditions. Beyond fertility, one of the most influential factors on crop yields is moisture supply. This varies not only annually but also geographically within the province and is dependant upon seasonal precipitation patterns and soil properties such as texture and drainage which affect moisture retention.

For wheat, barley and oats the recommendations (both Standard and Target Yield) provided are "moisture modified" in that they are designed to be more specific to crop yield potential and nutrient requirements under different average available moisture levels

encountered in different areas within Manitoba. Recommendations for other crops will become "moisture modified" as research results become available to permit this modification.

IV. SOIL FERTILITY AND FERTILIZERS

Extensive research has shown that there are seventeen essential nutrient required by plants for them to grow and develop normally. Early plant scientists originally thought that water was the only source of nutrition for plants. Experiments later proved that plants grew better if they were grown in soil with water added than if they were grown in water only. It was later proven that nutrients are not only in the soil, but also in the air. These seventeen nutrients are listed below, along with some general characterisitcs:

Essential Plant Nutrients

A. Supplied from Air and Water

- Carbon (C)
- Hydrogen (H)
- Oxygen (O)

B. Supplied from Soil and Fertilizer Sources

Major or Macronutrients

- Nitrogen (N)
- Phosphorous (P) — Primary nutrients
- Potassium (K)

- Sulphur (S)
- Calcium (Ca) — Secondary nutrients
- Magnesium (Mg)

Minor or Micronutrients

- Zinc (Zn)
- Copper (Cu)
- Iron (Fe)
- Manganese (Mn)
- Boron (Bo)
- Chlorine (Cl)
- Cobalt (Co)
- Molybdenum (Mo)

Of the 14 essential soil supplied nutrients only four macronutrients -- nitrogen, phosphorous, potassium and sulphur -- are likely to be of concern to crop production. Almost all productive soils in Manitoba contain enough of the other elements for crop production.

The two secondary macronutrients, calcium and magnesium are contained in lime which is plentiful in most soils. They create no deficiency problems for Manitoba crops.

Research has found only a few, very specific soil conditions where inadequate levels of minor elements occur. Situations in which micronutrient deficiencies limit crop yields are rare and so there is little chance of getting an economic response to micronutrient fertilization.

The following is a brief description of various nutrients and some suggestions on application procedures for the more commonly used fertilizers.

Nitrogen

Even though there are nearly 5 kilograms of nitrogen in the air for every square foot of the earth's surface, nitrogen is still the one nutrient which is most often deficient for plant growth. This is because the plant cannot absorb nitrogen directly from the air. It must first be combined with some other product to stabilize it and make it available for the plant to utilize.

Nitrogen is an essential part of every plant cell. If nitrogen is deficient, the cells will have a difficult time reproducing themselves, which is what cells do to cause growth. Nitrogen also makes plants greener and more succulent, adds yield and protein to the plant and makes them mor palatable by increasing the proportion of water to calcium in the plant tissues.

A plant with sufficient nitrogen also is more efficient at utilizing available moisture in drought years and increases the cation exchange capacity of the plant to give it an increased ability to absorb phosphorous, potassium and calcium.

Nitrogen is absorbed as either an ammonium or nitrate ion. Neither of these two forms can be stored in the soil for any length of time and must be replaced on an annual basis.

The efficiency of fertilizer nitrogen in increasing yield and/or protein content depends upon losses of applied nitrogen which are affected by time and method of application. Generally, application of 60 kg/ha of nitrogen or less to soils low in available nitrogen mainly increases yields. When soil available nitrogen content is high or more than 60 kg/ha is applied, both yield and protein content are increased.

Annual crops utilize about 20 to 60% of the applied fertlizer nitrogen. The amount of applied N utilized depends upon the availability of soil nitrogen and the losses of applied N. Reactions causing losses and the temporary fixation of nitrogen and methods of reducing them include:

1. Ammonium Fixation -- The ammonium form of nitrogen is temporarily retained or fixed by some clay minerals. Much of this nitrogen can probably be used by crops at some time during the growing season. Ammonium fixation is not likely a mojor factor by which fertilizer nitrogen is made unavailable to plants.
2. Ammonia Volatization -- Nitrogen from ammonium fertilizers can be lost as ammonia gas. Ammonia volatization increases with increasing soil pH, soil carbonate content, and pH of the added fertilizer. Losses of this type can be greater with urea and solution fertilizers containing urea than with ammonium-nitrate fertilizers. Losses are greater from alkaline than from acid soils and are higher under dry as compared to wet soil conditions. The losses from sandy soils are usually higher than from heavier textured soils and are greater at high temperatures than low temperatures. Ammonia loss also occurs from anhydrous ammonia and aqua-ammonia when soil conditions do not permit a good seal behind the application shank. The loss for all fertilizers can be eliminated or reduced to negligible amounts if fertilizer is well covered by soil.
3. Leaching -- This is the movement of nitrate-nitrogen in the soil solution below the root zone. Losses are minimal during winter and

the growing season. However, losses of nitrogen can occur during late fall or early spring in sandy soils. Very little nitrogen is leached from clay soils. Leaching losses of nitrogen applied in spring close to the time of seeding are minimal on most soils. Leaching losses are also reduced by adding an ammonium form of fertilizer banded into the soil.

4. Erosion -- Nitrogen fertlizer can be lost in run-off waters and through soil erosion caused by wind and water. Cultural methods to control wind and water erosion should be applied to minimize losses. Do not apply fertilizers to frozen soils. Run-off losses of applied fertilizers are also reduced by placement of the fertilizer into the soil.

5. Immobilization -- This activity is the conversion of inorganic nitrogen (plant available nitrogen) to organic nitrogen (plant unavailable) by soil micro-organisms. This nitrogen is not completely lost to plants but is released slowly in later years for crop use through mineralization. Ammonium nitrogen immobilization is slightly greater than immobilization for nitrate-nitrogen. Immobilization removes considerable amounts of inorganic nitrogen from the available form (20-40%). Band placement of nitrogen rather than broadcast application may be used to decrease losses by immobilization.

6. Denitrification -- Denitrification is the reduction of nitrate-nitrogen to nitrogenous gases such as nitrogen and nitrous oxide which are lost to the atmoshpere. In Manitoba considerable nitrate-nitrogen may be lost by denitrification when soils are temporarily wet. These wet conditions occur most frequently in late fall and early spring. Such losses are minimized by applying nitrogen close to the time the crop requires it. Losses can generally be reduced by adding an ammonium form of fertilizer banded into the soil. Banding ammonium fertilizer reduces the rate of nitrification (the production of nitrate-nitrogen). Research is being conducted to evaluate the use of additives to nitrogen fertilizers that may reduce the rate of nitrification.

Most commercial nitrogen fertilizers are water soluble, dissolving in the soil to give ammonium nitrogen (NH_4^+) and/or nitrate nitrogen (NO_3^-). Urea fertilizer may dissolve without alteration under cold soil conditions. Ammonium-nitrogen through the process of nitrification may be changed to nitrate-nitrogen. Although both nitrate and ammonium-nitrogen are available to plants, they behave differently in the soil. Nitrate-nitrogen and unaltered urea do not become attached to the soil. As a result they can move freely in the soil solution and be subject to leaching. By denitrification, nitrate-nitrogen can be lost to the atmoshpere. Ammonium-nitrogen is held in an exchangeable form by the soil with small amounts present in the soil solution. Although ammonium-nitrogen is immobile in the soil it can be lost by ammonia volatilization. Since nitrogen added to soils in the ammonium form is usually changed to nitrate-nitrogen, any nitrogen added in the ammonium form is eventually subject to leaching and denitrification. Nitrification occurs rapidly under warm and moist soil conditions but proceeds slowly in cold soil condition. It is also much slower when fertilizer is banded rather than mixed with the soil. In addition to the losses from the soil system, applied nitrogen cn be immobilized. Ammounium-nitrogen is also subject to fixation by clays.

METHOD OF PLACEMENT AND TIME OF APPLICATION

The efficiency of nitrogen in increasing yield and/or protein content is significantly affectd by the time of application and method of placement. Type of nitrogen fertilizer does not influence nitrogen fertilizer effectiveness if all fertilizers are applied so that nitrogen losses are minimized. Ideally, nitrogen fertilizer should be applied close to the maximum grwth period. For annual crops, the optimum time of application is near seeding. Time and method of application should be based on needs of the ceral, the potential for losses from the soil and fitting the soil fertility program into the efficient overall management of the farm.

A. Methods of Placement

Drilled with the seed -- This method is one of the most effective means of adding nitrogen fertilizer. Total amount of fertilizer material placed with the seed should not exceed 195 kg/ha. If seed bed moisture conditions are favorable, up to 45 kg N/ha can be applied with the seed. For cereals, not more than 22 kg N/ha in the urea form should be applied. Urea in excess of 22 kg N/ha causes seedling damage and reduces yield increases. Urea should be applied with the seed only on loam or heavier-textured soils and only if the seedbed is moist at the time of seeding. Nitrogen fertilizer should not be added with flax, sunflowers, corn, canola, buckwheat or mustard seeds.

Sideband placement -- Application through this method is equal in effectiveness to nitrogen drilled with the seed. It has the advantage that higher amounts can be used. One drawback is that equipment for sidebanding fertilizer is not readily available except for row crops. The nitrogen requirements for all crops can be applied in this manner without causing seed or seedling damage when the solution or dry nitrogen fertilizer is placed at least 5.0 cm from the seed row. Anhydrous and aqua-ammonia may be sidebanded to row crops if applied about 20 cm from the row.

Banded into the soil prior to seeding -- Based on a limited number of experiments, this method of placement is about equal in effectiveness to sidebanding or with seed placement. It is the best method of application when nitrogen fertilizer cannot be applied with the seed or sidebanded. Dry or solution fertilizer is applied in a band behind a shank or disc at depths of 7.5 to 10 cm. Aqua and anhydrous ammonia is applied at depths of 10 to 15 cm and about 5 days prior to seeding. Placement of fertlizers should be deeper for dry soils than moist soils and and deeper in sandy soils than in loams or heavier textured soils. Narrow band spacing (35 to 40 cm) is better for small grains than wider band spacing.

Broadcast and incorporated into the soil -- This method may not result in yield and/or protein increases as large as those obtained with band placement. To minimize volatilization losses, urea and

liquid or dry fertilizer containing urea should be well covered with soil. Shallow incorporation of these fertilizers may result in ammonia volatilization. When incorporation is not desirable due to moisture or soil conservation reasons, losses are reduced by applying the fertlizer at temperatures of 10 degrees C or less.

Broadcast without incorporation -- This method usually results in the least efficient use of fertilizer nitrogen. Ammonia volatilization can be appreciable resulting in lower yield and/or protein content than that obtained when the fertilizers are incorporated. Urea and dry fertilizers containing urea, and especially solutions containing urea which are sprayed onto soil surfaces are subject to ammonia volatilization. Yield increases are more dependent upon rainfall with surface placement then when nitrogen is placed in the soil.

B. Time of Application

At or near time of seeding -- Nitrogen fertilizer applied in the spring at seeding is usually more effective for increasing yield and/or protein content than adding nitrogen in the fall. Nitrogen fertilizer applied from one to two weeks prior to seeding or applied two to four weeks after seeding is about equal in effectiveness for a particular rate and method of placement.

Some crop damage (leaf burn) may occur if nitrogen solution is sprayed on leaf surfaces. Canola, flax, corn, and sunflowers are particularly susceptible to damage. Cereals have been sprayed with nitrogen solution at 45 kg N/ha with minimal damage and no reduction in yield increases. Leaf burn is minimal under cool, wet conditions. Rain, or irrigation, immediately following nitrogen application washes all leaf surfaces free of nitrogen resulting in no damage. Broadcasting granular fertilizers does not cause damage unless the foliage is wet.

Nitrogen fertilizers can be added to row crops following crop emergence. All fertlizers should be applied about 20 cm from the row. Exercise care so that plants are not damaged by equipment.

Fall -- Nitrogen applied in the fall has usually not given yield and/or protein increases as great as those obtained when equal amounts are added in the spring. Losses due to leaching, gaseous

loss, immobilization and weed growth are probably higher for fall applied than for spring applied nitrogen. This accounts for the differences in yield and protein content.

The relative efficiencies of nitrogen fertilizers as affected by time of application and method of placementy vary from year to year, with soil type and with climatic conditions. Below are the average relative values of itimes and methods of application. when spring broadcast nitrogen is assigned a value of 100:

Time and Method	Relative Value
Spring broadcast	100
Spring banded	120
Fall broadcast	82
Fall banded	93

Since in most cases, soil test recommendations are based on spring application of nitrogen, upward adjustments are made when it is applied in the fall. If a recommendation that 60 kg/ha be applied in a spring broadcast application, about 73 kg/ha should be applied if fall broadcast. About 65 kg/ha should be applied in a fall banded application to ensure a similar nitrogen supply.

PHOSPHORUS

Phosphorus is contained in the nucleus of every plant cell. If phosphorus is deficient, the cells cannot divide and growth is restricted. Generally, the the greatest concentrations of phosphorous are found in the growing points and tips of plants, where the cells are most actively dividing.

Plants will normally grow slower in cool, wet spring conditions. Quite often they also show a slight purplish discoloration if insufficient phosphorus is available. The addition of phosphorous to these soils and plants helps plants to grow more vigorously under adverse conditions, and they do not show the purplish coloring.

Phosphorus is also essential for the plant's cooling system to operate properly. Tiny opening in the leaves, or stomata, are use buy the plant to transpire water, in effect sweating to help keep the plant cool in the hot summer. Phosphorus deficiencies restrict the

opening of these stomata, and plant temperature can rise an extra 4 degrees C, placing an additional stress on the plant.

Most Western Canadian soils are phosphorus deficient and will give yield responses to fertilizer phosphorus application. Early work in Western Canada has shown the advantage of applying nitrogen with phosphorus. This has lead to the widespread use of monoammonium phosphates such as 11-48-0 and 11-55-0 as fertilizer phosphorus sources.

Economic rsponses depend on the quantity of plant available phosphorus in the soil. Soils testing low in available phosphorus will give an economic yield response almost 100% of the time. Crops grown on soils testing very high will respond to phosphorus 25 -30% of the time. On these soils a "starter" or "pop-up" effect is sometimes obtained, especially if soil water and temperature are both low in the month after seeding. The starter effect occurs only when fertilizer phosphorus is banded with or placed near the seed. Even in situations where large yield increases are obtained, the use of the fertilizer phosphorus by the plant in the year of application may be as low as 10% and seldom exceeds 30%. The unused phosphorus (residual phosphorus) remains in the surface horizon of the soil and may be used by subsequent crops, although its availability decreases with time.

The ideal situation for plant nutrition is to have a good supply of phosphorus close to the seed during the first month of growth and an adequate amount of phosphorus in the soil for the rest of the season. Placement of phosphorus with the seed or close to the seed have been the traditional methods for phosphorus fertilization in Manitoba. This method satisfies both the early growth requirements and provides a reserve of phosphorus for the balance of the growing season.

Methods of phosphorus application recommended in Manitoba are based on crop sensitivity to phosphorus placement, root morphology, phosphorus requirements of crops and phosphorus availability in the soil.

1. Phosphorus_banded_with_the_seed -- Banding of fertlizer phosphorus with the seed is the most efficient means of phosphorus application for all crops provided that the amount applied is not injurious to the germinating seedling. Some crops will tolerate all their fertilizer phosphorus requirements placed with the seed. (Cereals belong to this group.)

2. Phosphorus_banded_near_the_seed -- Banding of fertlizer phosphorus near the seed is the most efficient means of applying phosphorus when amounts in excess of those tolerated with the seed are required. Most oilseeds, annual legumes and row crops require some or all of their fertilizer phosphorus placed in this manner.

3. Phosphorus_surface_applied_and_incorporated -- Surface incorporation of fertilizer phosphorus is the least efficient means of applying this nutrient. The amount applied broadcast must be several times greater than amounts applied with or near the seed to obtain equal yield increases in the year of application.

Increasing the amount of phosphorus applied above that normally recommended will result in a greater increase in soil available phosphorus when compared to smaller amounts applied with or near the seed. Producers could increase soil available phosphorus to high or very high levels so that yields would not be significantly affected by phosphorus deficiency. The number of such applications or years of phosphorus fertilization required to increase soil available phosphorus to high or very high levels is unknown for most soils. Soil testing at regular intervals is a good way to monitor the available phosphorus level.

Since the amounts of phosphorus applied during the first number of years have to be increased two- to four-fold to equal yield increases from placement near the seed, broadcast applications of phophorus may be uneconomical on many soils.

Broadcasting very large amounts of phosphorus (eg. 400 kg P205 per hectare) with the idea of eliminating annual application is highly questionable. These treatments have very good residual effects and will result in yield increases for several years after application. Net returns from this type of application, though,

will be even lower than from annual application. This is due to the very high initial investment and decrease in plant availability of applied phosphorus with time. Applications of this nature could be used to increase soil available phosphorus and yields when portions of a field, such as eroded knolls, are very low in available phosphorus in comparison to the remainder of the field. The eroded knolls could be fertilized with large quantities of phosphorus and then treated similarly to the remainder of the field with respect to annual application of phosphorus. High rates of applied fertilizer P may induce a micro-nutrient deficiency where soil levels of micro-nutrients are marginal (eg. zinc and copper).

4. Deep banded -- Deep-banding phosphorus (banded at a soil depth of about 7 to 10 cm and 17.5 cm spacing prior to seding) was better than broadcast phophorus applications. It was about equal to the with-seed application for most test stations in Manitoba. However, in these experiments, phosphate band spacing was relatively narrow at 17.5 cm, resulting in only a 9 cm distance from the seed to fertilizer band.

Studies conducted in Manitoba and elsewhere on the Canadian prairies have shown a significant increase in fertilizer phophorus uptake by plants when nitrogen in the ammonium form was applied in contact with the phosphorus. Also, adding nitrogenous fertilizers with phosphorus may increase phosphorus solubility in the fertilizer band. This results in more phosphorus fertilizer being available.

Research work comparing deep-banding of phosphorus and nitrogen together as compared with phosphorus alone banded near the seed has been done in several locations. Initial information shows that pre-plant deep-banding of phosphorus with nitrogen at spacings of about 30 cm was superior to phosphorus being placed with the seed and the nitrogen being deep-banded before seeding. Two reasons for the greater yield increases with the pre-plant deep-banded phosphorus with nitrogen are:

1. A greater uptake of phosphorus by plants from the deep-banded phosphorus. Phosphorus uptake by plants is severely limited by low soil moisture content. Uptake from bands placed at

shallow depths, which occurs when phosphorus is placed with the seed, may be less than that from deep-banded phosphorus under dry conditions.

2. Seed and seedling damage from the large quantity of phosphorus placed with the seed for experimental purposes may have also reduced yields.

POTASSUIM

Potassium is a key ingredient of the protein manufactured by a plant. As much as one third of the plant's total potassium is fixed in this form. It also aids in the movement and translocation of carbohydrates within the plant and increases the disease resistance and frost tolerance of most plants.

Most soils in Manitoba have high levels of potassium in them, yet the amount of potassium which is applied goes up every year. A possible explanation for this apparent excess is the fact that potassium is usually fixed in the soil in a form which is unavailable to plants. Normally, only about 10% of the applied potassium is available for plant use in the year of application.

Manitoba's sandy lands are generally considered to be the only soils in the province which are seriously deficient in potassium, but if high users of potassium such as corn are grown, it may be advisable to investigate the application of this fertilizer. In any case, it is always best to get a soil test.

SULPHUR

Again, most soils in Manitoba are not deficient in sulphur for most cereal crops. Deficiencies have been detected in Grey Wooded soils as well as some other soils around the province when they are used to grow canola and other oil seeds. Sulphur is a constituent of the oil produced by members of the cabbage family, of which canola is a member. It is also required for the synthesis of certain vitamins in plants.

MAGNESIUM AND CALCIUM

The two secondary macronutrients calcium and magnesium are contained in lime which is plentiful in most soils. They create no deficiency problems for Manitoba crops.

ZINC AND COPPER

Some of Manitoba's highly calcium carbonated (calcareous) soils have low levels of available zinc, potentially limiting production of crops requiring high levels of zinc such as corn and beans. Available levels of copper (and/or occasionally manganese or boron) may be low for producing come crops on deep organic soils, depending upon the nature of the peat, the underlying material and soil moisture and temperature conditions. Available copper levels may be marginal on some very coarse (sandy) textured acidic soils.

IRON AND MANGANESE

Usually iron and manganese levels are high in Manitoba soils. But their availabiltiy is affected by aeration of the soil, which is related to soil moisture content. Heavier textured, poorly drained soils are most often affected. Nothing practical can be done to increase the availability of native soil iron and manganese.

BORON

Boron is often applied during production of horticultural crops such as rutabagas, cabbage, cauliflower and brussel sprouts to ensure against problems affecting crop quality and storage properties. There is no evidence that economic responses to boron are obtained or that, under field conditions, production of common field crops is restricted by its availability.

No problems involving other micronutrients have been detected, although cobalt, molybdenum and selenium amy be important to livestock nutrition.

Plants contain nonessential elements derived from the soil, such as sodium and aluminium. These play no functional role but can cause problems to the plant or its consumers if high levels are present in the plant. In Manitoba, factors leading to such high levels rarely occur.

V. PLANTS

Early man probably became a farmer when he (or she) discovered that seeds dropped into rubbish heaps (or otherwise disposed) grew up to produce more plants of the same type. The greater ease with which food could be produced likely caused man to abandon his nomadic ways and settle down, thus developing the more permanent communities. Undoubtedly he recognized early that plants grew best in some places. The most permanent settlements developed where there was early appreciation of crops and soils.

Plants are extremely variable in their size, for example, from single-celled bacteria (1/63,500 cm long) to the giant Redwoods of California (up to 61 meters high with a circumference of 29 meters). Some forms such as some bacteria and fungi, are the cause of diseases of plants, animals and man. Others provide materials for antibiotics and other drugs. Many plants provide the food and materials for shelter and clothing. Green plants provide much of the oxygen which is so essential to man and animals.

A. Kinds of Plants

All plants are composed of single cells or groups of cells, which is reason enough to group them into various kinds. This feature, along with others is used in their classification.

Some groupings are:

1. Non-green plants -- plants which are not capable of manufacturing their own food. This group includes (a) bacteria, which are single-celled, and (b) fungi, which includes yeast, mold, mildew, smuts, rusts, and mushrooms, toadstools, etc.
2. Green plants -- plants which contain chlorophyl, derive energy from the sun, and manufacture carbohydrates from nutrients in the soil and CO2 from the air. This group includes algae (single-celled), mosses and liverworts, ferns and horsetails (reproduced by spores) and seed plants.

In Manitoba, there are distinct areas whic are characterized by the type of native vegetation found there. These include:

1. Grassland -- native vegetation is perennial grasses on an almost treeless plain. This area is subdivided into:
   (a) South Western Manitoba - characterized by short prairie grasses in an area of annual precipitation betweem 40 - 45 cm, warm summer temperatures, and periods of droughts.
   (b) Red River Plain - characterized by tall and meadow grasses, lusher growth and moist soils. Annual precipitation ranges between 46 - 51 cm and warm temperatures, and periods of droughts.
2. Prairie - Aspen Grove -- characterized by predominantly grasslands, but in the past, shrubs and shrub-like trees have invaded. This occured because of higher precipitation (47 - 50 cm approximatly) combined with cooler temperatures and therefore, a more humid climate.
3. South Eastern Forest -- characterized by coniferous forest interspersed with peat bogs. Oaks and maple grown on well-drained sites.
4. Boreal Forest Region -- in area east of Lake Winnipeg, northern Interlake, etc. Characterized by mixed deciduous (broad-leaved) and coniferous (evergreen) trees. Frequent peat bogs occur because of drainage problems. This is an area of cool temperatures and approximately 50 - 58 cm of precipitation annually.

The soils that have developed in Manitoba were strongly influenced by the native vegetation.

B. PARTS AND FUNCTIONS OF A PLANT

1. Seeds

A seed consists of an embryonic plant in resting condition. It is surrounded by stored food and a seed coat. The bean seed can be used as an example of a representative seed.

The two large halves of the embryo (used by humans for food) supply food for the developing seedling and are called cotyledons. (In monocotyledons the food for the embryo is the endosperm.) Below the cotyledons is the hypoctyl which develps into the stem. At the base of the hypocotyl is the epicotyl which develops into leaves when the stem emerges above ground.

Germination of a dicotyledon -- When the seed is planted in conditions suitable for growth (water, oxygen, favorable temperature), water is absorbed and the cotyledons swell and rupture the seed coats. The radicle grows down into the soil (due to a positive response to gravity) and develops into a root. The hypocotyl then lengthens (negative response to gravity) and lifts the epicotyl above ground. (In some plants the cotyledons are also lifted). The cotyledons supply food until the primary leaves have developed, then, having been used up, wither away. The roots have developed and the new plant is on its own.

In monocotyledons (grass plants), the single cotyledon remains within the germinating seed and never emerges above ground.

The first signs of germination are the swelling of the seed and softening of the seed coat by water. If the temperature is favorable, the embryo becomes activated by enzymes which have dissolved in the water within the seed, and begins to grow. (This is a critical period in the development of plants. If the seed coat has been broken but soil temperatures are too low for activation of the embryo, the seed may rot in the ground.

The enzymes change the starch in the cotyledons or endosperm to sugars, which are used by the embryo. Respiration increases quickly and CO2 is released.

Green plants can be further divided by seed characteristics:

(a) Gymnosperms -- which have naked seed (pine trees)

(b) Angiosperms -- which have well-developed flowers and seeds. Angiosperms are further divided, as shown earlier, into:

(1) Monocotyledons - plants of the grass family including wheat, oats, barley, etc. The seeds have one cotyledon

and the leaves have veins which run parallel to the leaf edge. The roots of these plants are fibrous.

(2) Dicotyledons - broad-leaved plants with netted veins (generally arising from a central mid-rib), the seeds have two cotyledons and the plant has a tap root.

Monocotyledons and dicotyledons are often grouped according to the characteristics and period of growth and reproduction.

ANNUALS -- Plants which develop from germinating seed, grow to full size, develop reproductive parts, set seed and mature and die in one year.

BIENNIALS -- Plants which germinate and grow vegetatively for one year, store foods in the roots and die back to the crowns at ground level at first frost. In the second year, they grow to full size, produce flowers, seeds and die off. (Sweet clover is a good example).

PERENNIALS -- Plants which are longer-lived than two years. They produce more than one setting of seed. They include herbaceous perennials, which are soft stemmed and leafed, and die back to ground level each year (ex. common grasses and alfalfa), and woody perennials such as shrubs and trees.

WINTER ANNUALS -- Plants which grow through the annual cycle, but may germinate in the fall, and die back to the crown at first frost. They rejuvinate in spring and continue the annual cycle. Fall rye and winter wheat are examples of these plants.

The types and numbers of plants found in any area of the world are stongly influenced by such factors as:

1. Climate, which includes temperature, precipitation, length of seasons.
2. Soil moisture, which is related to internal drainage, aeration and nutrient availability.
3. Light intensity and length of period of light.
4. Soil type and topography.
5. Relationship with other plants and animals.

Each type of seed has its own range of temperatures within which it will germinate. Few types germinate until soil temperatures reach 5 degrees C (cereal grains germinate at low temperatures; corn requires soil temperatures above 10 degrees C.)

2. ROOTS

The prupose of roots is to:

(a) absorb water and minerals;

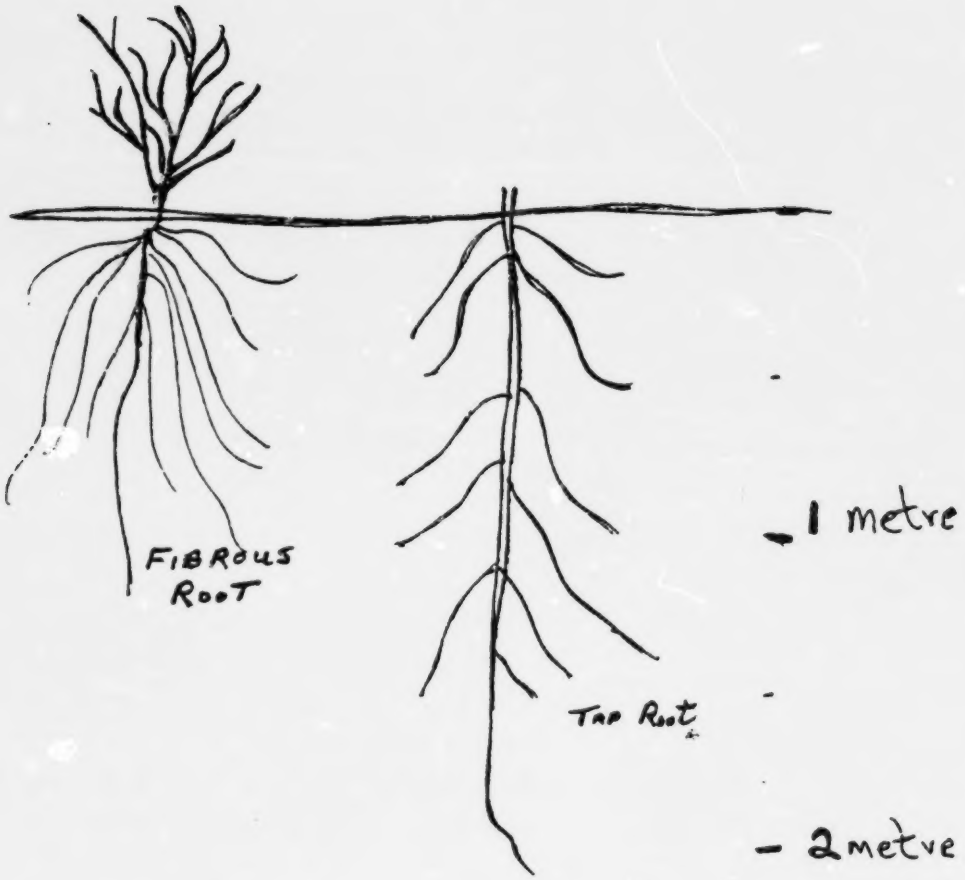
(b) anchor the plant in the soil;

(c) sometimes to store foods.

The root tip is the first part of the embryo to develop. It elongates and develops a primary root from which secondary roots branch off. Lateral roots branch from the secondary roots and produce the root hairs which absorb the water and necessary elements. These root hairs develop quickly and live only for a short time, new ones are forming on new lateral roots as the whole root system develops.

The root system may equal or exceed the amount of above-ground growth of a plant. A single sugar beet root, for example, may extend 150 - 180 cm underground and have a spread of lateral roots of 180 cm. Cereal crops commonly root to 120 cm below ground, but since they are grown in narrow rows (15 or 17 cm spacing) seldom extend far laterally under field conditions. Alfalfa may root to 180 cm or more. The extent of root development will depend on soil conditions, such as compaction, soil moisture supply and competition with other plant roots.

There are two main types of root systems: fibrous and tap. In fibrous systems, the roots are slender and fibre-like, developing from a central point with no one root predominating. This is characteristic of grasses, cereals and other monocotyledons. The tap root system has a main root that grows directly downward. Lateral roots develop out from the central tap root. Tap roots may be fleshy like carrots, beets and turnips, or slender like clover, etc. Fibrous roots often do not develop as deeply as do some tap roots like alfalfa or some tree roots.



Some plants can develop adventitious roots from nodes on underground stems or rhyzomes. These are a different type of roots than are normally found on most plants because they do not grow from the crown of the plant. This is a characteristic of quack or couch grass which is common in this area, and makes it difficult to eradicate.

3. STEMS

The function of stem is to:

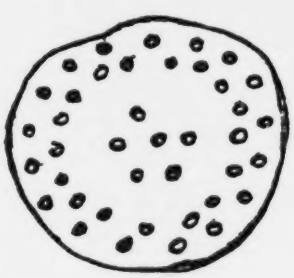
(a) support the plant and expose the leave to the sun;

(b) act as conduction tissue for water and minerals to the leaves from the foots, and sugars to storage. The stems of monocots differ in structure from those of dicots.

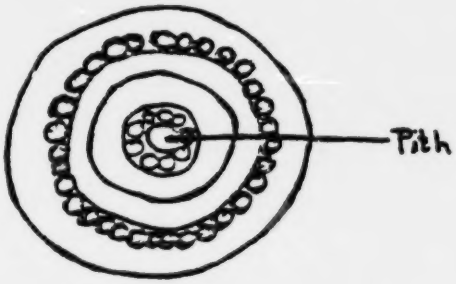
Monocots -- the veins which carry water to the leaves and carbohydrates to storage occur in bundles, called vascular bundles.

These vascular bundles are scattered throughout the pith in the stem, and are more concentrated on the outer edge.

Dicots -- vascular bundles are arranged in rings around the pith. In woody dicots, the pith is very small in comparison to herbaceous (soft) dicots.



Monocot Stem



Dicot stem

Nodes and Internodes of stems -- A node is the region of a stem where a leaf or leaves are attached. The regions between the nodes are internodes.

The exchange of CO2 and O2 between the stem and the air is essential. This takes place through small breaks or openings on stems called lenticels. These lenticels, though, are only a secondary area of exchange when compared to the stomata on the leaf.

4. LEAVES

The primary functions of the leaves are:

(a) to manufacture food. In the plant, the process by which chlorophyl converts the sun's rays into chemical energy and brings about the reaction of CO2, water and nutrients into carbohydrates, protein, etc. is known as photosynthesis.

(b) to allow respiration to occur - this is the intake of CO2 through opening (stomata) in the leaves and the giving off of O2.

(c) to allow transpiration of water. The giving off of excess water which has transported the nutrients form the roots to the leaves. Dicot leaves typically have tow parts, the blade and

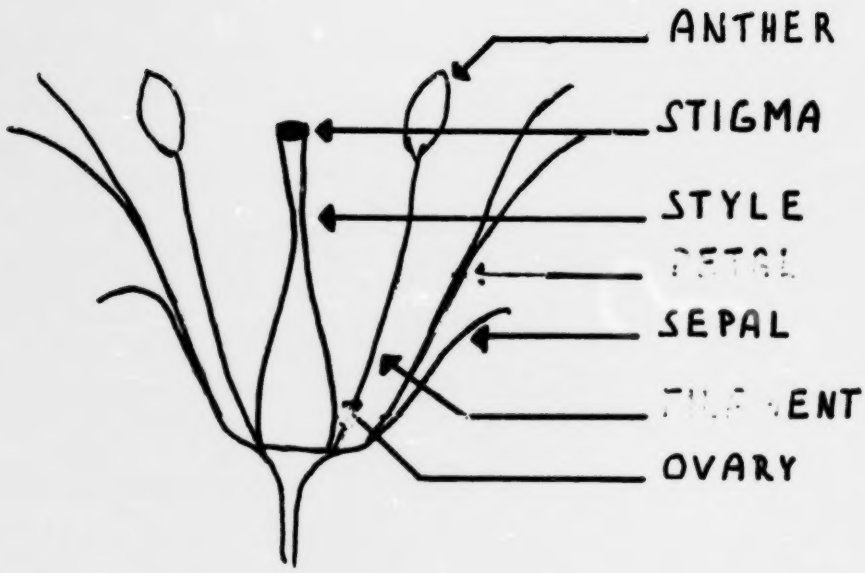
the petiole or stalk. Dicot leaf veins are characteristically netted, i.e. the veins arise from a central mid-vein and branch out. In monocots, the veins of the leaves typically run parallel with the leaf edge.

5. FLOWERS

The function of the flower in most plants is for reproduction. Many plants have attractive and scented flowers which attract insects, birds, etc., which aid in the mechanics of reproduction.

A typical flower consists of sepals, petals, stamens, and pistil. The sepals enclose the other parts of the flower while in the bud. The petals are usually the colored parts of the flower and as a group form the corolla. Stamens are the male parts and are made up of filaments and anthers which contain pollen. The pistil is the female part and consists of a stigma or surface on which the pollen lights, the style which serves as a support for the stigma and the ovary in which the egg or seed is born. Seeds develop in the ovary when pollen reaches and fertilizes the egg.

Some plants have both male and female parts and are self-fertilizing (ex. cereal grains and corn). If male or staminate flowers occur on one plant and pistilate or female flowers on another plant, then those plants are cross-pollinating. Agents of pollination are wind, insects, animals, water or any agent which transfers pollen from the male flowers to the stigma of the female flowers.



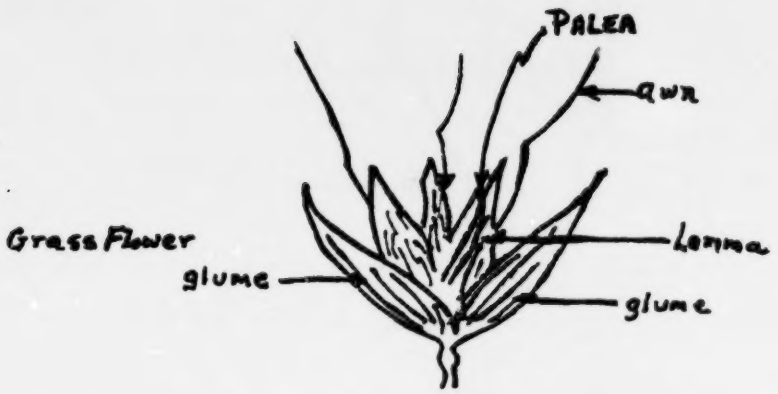
The Grass Flower

Grasses are extremely important plants to human. Members of the grass family are such crops as wheat, oats, barley, rice, corn, cugar cane, and bamboo. These plants do not have colorful, scented petals, but are rather inconspicuous.

One or more flowers grow together in a small cluster called a spikelet enclosed by two scales called glumes. In wheat, barley and some grasses, the spikelets are attached directly to the main stem (rachis) and the complete "head" is known as a spike. In oats, the spikelets grow at the ends of branches of the rachis and the "head" is called a panicle.

While we speak of a "head" of wheat, this is an incorrect term. A head is a crowd of flowers that are borne on an expansion at the tip of the stem. Sunflowers, asters, chrysanthemums and dandelions have heads.

When a pollen grain is transferred from the anther (where it is formed) to the stigma of the female part, this is known as pollination. On the stigma, the pollen grain germinates and sends a tube through the stigma and stule into an ovule where it releases two sperms. One unites with the egg and develops into a new plant. The second unites with a polar nuclei and develops into endosperm. The ovule then develops into a seed and ovary into a fruit.



C. REPRODUCTION OF SEED PLANTS

Sexual Method - Self-Polination -- If the pollen is transferred to the stigmas of flowers on the same plant, self-pollination results. In plants like garden peas, wheat, oats, and cotton, self-pollination is the rule.

In the development of new varieties of wheat, oats, etc., the stamens are often removed by the plant breeder and pollen from the other plants is introduced to the stigma.

Cross-Pollination -- This occurs when pollen is introduced to the stigma of a plant from the stamens of another plant, and the crossing is done by nature. In plants like oak, willow, cottonwood, all pollination is cross-pollination because male and female parts are found on different trees. In other plants cross-pollination occurs because the pollen is released when the stigma on that same plant is not receptive.

Pollinating Agents

1. Wind -- in general, plants which lack characteristic flowers, petals, odor or nectar are pollinated simply by the chance that wind will blow the right pollen onto a stigma. Plants which depend on wind are grasses (including wheat, barley, oats), cottonwoods, elms, oaks, and ragweed.

2. Water -- some plants that live in water must be pollinated by water transporting the pollen.

3. Birds -- ex. hummingbirds getting nectar transfer pollen.

4. Insects -- flowers have many devices which attract insects. These include conspicuos petals, fragrance and nectar. Pollen becomes stuck to the insects, which then transfer it to other flowers. Bees are among the best pollinators. Often bee hives are placed in fields to improve seed set of some plants. This includes sweet clover, alfalfa, canola and buckwheat.

After fertilization, the seed develops and the plant matures. The cycle is complete. The seed may, if conditions are favorable, germinate the next year and produce a new plant. The favorable conditions may be provided by the farmer who wishes to obtain more of the kind -- or the farmer may harvest the seed and make it available as food.

Asexual Methods

When parts of plants other than seeds are used to reproduce a plant, this is known as the asexual method. This method is used to propagate fruit trees, some ornamental plants, sugar cane, pineapple, raspberries, potatoes, etc. All of the offspring are genetically identical to the parent.

Plants may be propagated asexually by specialized stems, root tubers, stem cuttings, leaf cuttings, root cuttings, budding and grafting.

Rhyzomes -- These are horizontal stems which grow below or at the surface of the soil. Like stems, they have buds which may branch. Several plants can be obtained by dividing rhyzomes into sections, each one containing a bud. Plants like iris, orchids, asparagus can be propagated this way.

Many weeds, including quackgrass and Canada thistle, propagate during the early and middle summer by rhyzomes. Cultivation, or discing of land, often cuts the rhyzomes up, making many more potential thistle or quackgrass plants. Often these have to pulled up to the surface by spring harrows so that they can be dried out in order to kill them, or they have to be worked up continually until

all food in the pieces has been used up by new roots, and the parts die. Glyphosate chemical (Round-up) is also very effective against these weeds.

Tubers -- These are thickened, fleshy underground stems (ex. potatoes). Potatoes are developed from pieces of tubers which have at least one eye (bud) on them.

Runners or Stolons -- These grow horizontally above the soil surface. New plants develop at nodes where the runner comes in contact with the soil. Strawberries are propagated from runners.

Corms -- These are short, upright underground stems which resemble bulbs. Gladiolus and crocus are frequently propagated in this way. Several to many small cormels are produced each year and these can be separated to produce identical plants.

Bulbs -- These consist of many fleshy scalelike leaves attached to a short stem which bears a shoot. Examples are lilies, tulips, hyacinths, daffodils and onions. After planting, the shoot emerges, and the scalelike leaves are used up as food.

Root tubers -- Thick fleshy root tubers of some plants can be used for propagation, provided a piece of stem with a bud on it is left attached. Examples of these plants are dahlias and peonies.

Stem cuttings -- sugar cane, carnations, chrysanthemums and geraniums are examples of non-woody plants propagated by stem cuttings. These cuttings are made by cutting off the terminal bud, just below a node, and leaving about 4 leaves on the cutting. The cutting is then placed in moist sand or peat until rooted, then planted in soil.

Leaf cuttings -- If the petiole of leaves of some plants is placed in moist soil, regeneration occurs at the base of the petiole. Such plants include African violets, begonia, gloxinias.

Root cuttings -- Most roots cannot regenerate shoots. There are, however, exceptions, and these include blackberry, raspberry, cottonwood, and horseradish. Weeds such as sow-thistle and field bindweed reproduce naturally by this method.

Grafting and budding -- Consists of joining together the parts of two different plants. The flowers and fruits developed from each part of the joint will be the same as the original plants.

NITROGEN FIXATION

Nitrogen is the most abundant element in the earth's atmosphere (80% by volume). As the main element in plant protein, nitrogen is required by plants in larger quantities than the other plant nutrients. However, the quantity in cultivated soils, in a form available to plants, is generally insufficient for maximum crop yields. This contradiction of nitrogen abundance and scarcity occurs because atmospheric nitrogen is not available to most plants.

By 1945, technological developments had led to increased mechanized farming. Traditional "legume cereal" rotations were abandoned. Legumes as a nitrogen supplier in the rotation were replaced by relatively cheap inorganic nitrogen fertilizers such as ammonium nitrate and urea. However today, because of the escalating costs of nitrogen fertilizer, there is a renewed interest in legume crops.

Farmers have long experienced the benefits of growing legumes in a crop rotation. When managed properly, they will:

--increase the soil reserves of nitrogen and organic matter
--improve soil structure
--reduce soil erosion and deterioration
--improve soil water holding capacity
--make the soil easier to till.

Legumes

Legume plants can enter into a "symbiotic" relationship with nitrogen fixing bacteria called rhizobium. Legumes supply the rhizobium with energy food called carbohydrates, which the bacteria cannot manufacture. The bacteria fix atmospheric nitrogen for the plants. Atmospheric nitrogen in turn, is changed to amino acids which can be used by the legume plants to manufacture protein.

Legume plants do not depend totally on nitrogen fixed by the bacteria. They can and will use soil nitrogen. In fact, when the available nitrogen level in the soil is very high (greater than 30 kg/ha nitrate-nitrogen), nitrogen fixation is very low and may be completely stopped. In these cases the legumes rely on soil nitrogen for growth and development rather than on fixed nitrogen.

The following plants are considered to be legumes because of their ability to fix nitrogen:

Perennial Forages -- Alfalfa, Trefoil

Biennial Forages -- Clovers

Oilseeds -- Soybeans

Grain or Pulse -- Fababeans, Peas, Beans, Lentils.

Researchers have found that the nitrogen fixation process is the most efficient way to supply the nitrogen requirements of legumes. This is because of the high cost of supplying the large quantity of fertilizer nitrogen otherwise needed to produce high yielding crops with a high protein content.

Each legume specie associates with a different rhizobium species. For example, the bacteria that associates with alfalfa to fix nitrogen, will not associate with fababeans. Many of the rhyzobium species required for effective nitrogen fixation with the new legumes being introduced in Western Canada, may be present in the soil only in very small numbers. To ensure successful legume crop inoculation, apply a commercial rhizobium inoculant with the seed.

Inoculation occurs when the bacteria infects tbe root hai[illegible] of the plant and forms nodules. These nodules are enlarged plant cells filled with bacteria. In the nodules the bacteria fixes nitrogen. Atmospheric nitrogen is obtained from the soil air spaces around the nodules.

To determine if nitrogen fixation is occurring, examine the crop roots for nodules. For annual legumes this examination should be done three to four weeks after emergence. Examining perennial and biennial legumes six to eight weeks after emergence is recommended. For established stands of forage legumes, an annual examination in early June is recommeded. Although the absence of nodules indicates there is no nitrogen fixation taking place, nodules themselves do not necessarily mean that nitrogen fixation is occuring. Only when the insides of the nodules are red to pink is nitrogen fixation taking place.

Energy Requirement of Nitrogen Fixation

Whether the process is chemical (fertilizer manufacture) or biogical, a large amount of energy is required to fix nitrogen in the form usable by plants. The energy required to fix nitrogen by the rhyzobium bacteria is supplied by the sun. In sunlight the plants manufacture carbohydrates in the green leaves. This energy producing food is distributed to all parts of the plant where it is either used immediately or stored in the roots or seeds for future growth.

In legumes, a large portion of the carbohydrates marufactured by the plants is tanslocated to the roots where they are used by the nitrogen fixing bacteria. Here the carbohydrates are a source of hydrogen to form ammonia (NH_3) with atmospheric nitrogen. Also, they supply the energy required to make the process go. With legume crops the fixation of nitrogen is accomplished by plants and sunlight which are renewable resources.

Quantity of Nitrogen Fixed

The amount of nitrogen which is fixed differs for different legume species and varieties. It is influenced by the environment and the management of the crop. For example, nitrogen fixation in highly alkaline and very saline soils, or under conditions of drought or excess soil moisture can be reduced considerably or stopped. For optimum nitrogen fixation, crops must be managed properly and conditions must allow for growth and development of the rhyzobium.

Most grain legumes fix between 50 and 70 per cent of their total nitrogen requirements. Some like fababeans fix up to 90% per cent. Established, and properly managed forage legumes will fix all their nitrogen requirements. At maturity, most of the plant nitrogen accumulates in the seed. Consequently, when the crops are harvested for seed or forage, most of the fixed nitrogen is removed from the soil. Only a small portion is returned to the soil as stubble and other crop residue.

When a legume crop is used in a rotation to increase soil nitrogen reserves, it must be managed as a green manure. This means that the crop should be cultivated into the soil when total nitrogen accumulation is maximum. For annual legumes this takes place at the

full pod stage. In forage legumes it occurs at the full bud or early flowering (5 per cent bloom) stage.

Quantity of Nitrogen Returned to the Soil

Estimates of the quantity of nitrogen returned to the soil either from a legume stubble or a green manure vary. Not all of the nitrogen returned to the soil is immediately available, though, in the year following the legume. Researchers have found that from an annual legume stubble as much as 35% may become available. For a green manure crop, a high estimate would be 50%.

The following table gives estimates of the quantity of nitrogen returned to the soil by various legume crops.

Crop	Stage of Growth	Total Nitrogen kg/ha
Alfalfa (5 Years)	Full bud	135
Sweet Clover (2nd yr)	Flowering	120
Soybeans	Full pod	80
Fababeans	Full pod	100
Peas	Full pod	65
Soybeans	Stubble	40
Fababeans	Stubble	60
Peas	Stubble	25

Note: Roots are not included. It is anticipated that because of the extensive root systems of forage crops the total nitrogen contribution to the soil would be increased considerably from the roots.

Nitrogen Fertilizer Requirements

The use of legumes in the crop rotation, either as a grain crop or a green manure does not eliminate the use of inorganic nitrogen on non-legume crops which may follow in the rotation. For optimum yield, fertilizer nitrogen may be needed. The amount required will be less than that needed for the same yield if the stubble was from a non-legume crop.

Nitrogen fertlizer requirements can only be determined by a soil test. Generally, however, non-legume crops grown after legumes in a

rotation have a high protein content. Nitrogen continues to be released from the legume residues throughout the growing season and accounts for this. Depending on the quantity of green manure and its nitrogen content, when incorporated into the soil, two or more crops of non-legume plants may benefit from the increased nitrogen reserves in the soil. Close monitoring by soil testing is necessary.

Other Benefits

Incorporation of legume residues either as stubble material or as a green manure rapidly increases the organic matter of the soil. This is because compared to cereal stubble or straw, legume materials are relatively easily decomposed. The increase in soil organic matter improves the soil structure. As a result the soil is easier to cultivate and its moisture holding capacity is increased.

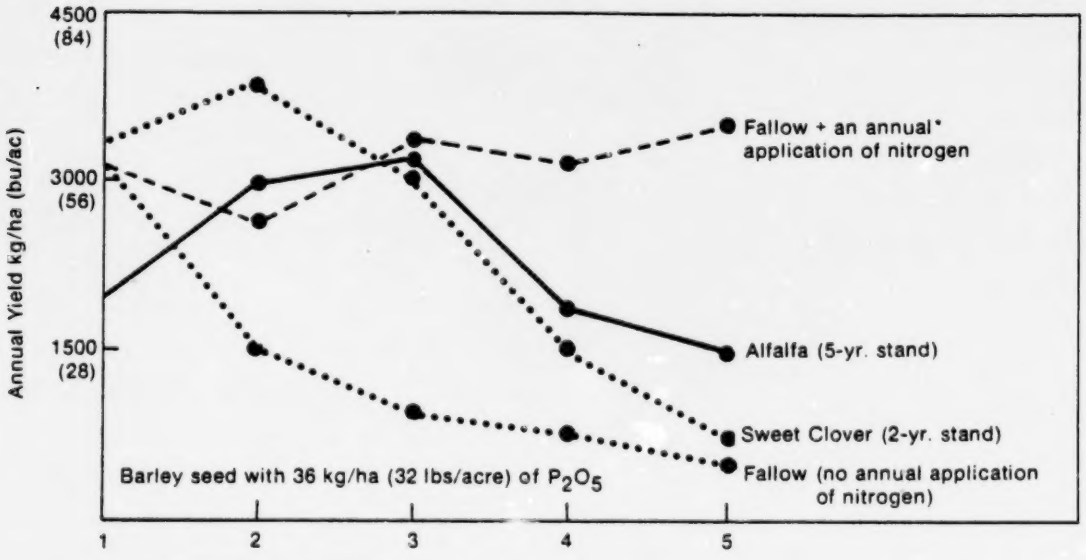
Cropping to forage legumes also checks developing salinity problems and may correct them. Alfalfa particularly, because of its high tolerance to salinity, deep roots and high water consumption can be used to check salinity and improve the soils. Deep root penetration by alfalfa has improved the internal drainage of soils. Incorporation of large quantities of green manure also improves the internal soil drainage.

Problems

Using legumes in the rotation has its problems. Weeds, diseases and cost are critical difficulties. Control of broadleaved weeds can be a problem; notably in forage legumes. Good weed control, particularly when a forage crop is to be kept for several years before breaking, is essential. Many legumes, especially annuals, are susceptible to soil borne diseases. Exercise care as to the frequency that legumes occur in a rotation or as to the crops they follow in the rotation (other crops are susceptible to some of the same diseases that infect legumes).

The practice of using legumes as a green manure in the rotation is expensive. Investigate and plan your program carefully. It demands a very high degree of management to achieve economic benefits. It is not an easy way of avoiding management decisions on the economics of crop production using inorganic fertlizers.

Annual Yield of Barley Over a 5-Year Period Following Forage Legume as Green Manure and Fallow



Year after fallowing or legume breaking

** The nitrogen rate was 90 kg/ha (80 lb/acre) in year 2 and 120 kg/ha (107 lbs/acre) in years 3, 4 and 5.*

VI. SEED AND SEEDING PRACTICES

Research work has shown that yields of our commonly grown field crops are most satisfactory when the seeding is done as early in the spring as working the land will permit. Delaying the seeding date by 23 days from early May to late May, has resulted in yield reductions of Neepawa wheat of 19%. Similar reductions in yield have been found with late seeding of barley. At Winnipeg, yields were reduced by 23% in 1953, and by 28% in 1954 by delaying seeding until June 9 and June 23 respectively. The same general trends apply to our more recent varieties as well.

Better yields with early seeding are likely due to: (a) getting the crop growing vigorously before rust epidemics strike, and (b) getting the crop to fill out and mature before very hot weather in late July.

Dates of Wheat Seeding

	Yields in Tonnes per Hectare		
	May 5	May 28	June 19
Neepawa 1973 -1976	3.238	2.612	1.534

Dates of Barley Seeding

	Yields in Tonnes per Hectare		
	May 5	May 28	June 19
Bonanza 1973 - 1976	3.935	3.706	2.290

R.I. Wolfe C.D.A. Research Station Brandon

Sometimes late seeding is necessary to give a farmer time to control an early growth of weeds. This is justifiable, particularly for weeds like wild oats. This practice must, however, be considered and compared with chemical methods of weed control. The practice followed should be the most economical one.

The land should not be worked more than is necessary to kill weeds and prepare a seedbed in spring. This means that land should

not be worked deeper than 5 - 7 cm. Land will dry out to the depth of cultivation and this will result in a hard, lumpy seedbed and cause poor germination. Deep tilling land in the spring will only dry the soil out to the depth of cultivation and should not be considered as a good practice on wet soils. Seed should be placed into moist soil, but not depths greater than 5 cm. Deep seeding frequently results in low yields, due to low percentage of plant emergence. Small seeds such as flax, rapeseed and mustard should not be sown deeper that 25 mm. The seedbed should be firmed after seeding so that moisture will move up around the seed (it will rise in small pores). Firm packing of peat soils is absolutely essential.

A. SEEDING RATES

Seeding rates vary depending on seed size, germination percentage, and variety. The following rates may be considered as a guide:

Wheat -- 64 - 135 kg/ha
Oats -- 55 - 115 kg/ha
Barley -- 65 - 120 kg/ha (preferably the lower to middle rate)
Flax -- 30 45 kg/ha
Canola -- 4 - 8 kg/ha

The higher range should be used if:

(a) the field is weedy; thick crops will shade out the weeds
(b) there are very good moisture reserves in the soil
(c) wireworms or cutworms may become serious pests
(d) low germination seed is being used (definatley not recommended)
(e) the seedbed is poor
(f) deep seeding is necessary
(g) discers are used as seeders

Seedbeds should be firm and moist. This condition is brought about by working land when it is not too wet or too dry (a very short period indeed on clay soils). Fall tillage with a heavy duty cultivator, plow or disc implement will improve workability in the spring. It will also help to bury some trash and allow the soil to

dry up and warm up earlier. Tillage however, should always be shallow (no grater than 10 cm). Excess tillage will make seedbeds dry and lumpy.

The best seedbed is obtained on fallowed land and is likely one of the reasons why yields are better on fallow. This is an expensive method, however, of obtaining a good seedbed. With proper care, tillage equipment and straw choppers, good seedbeds can be prepared on stubble.

SEED SELECTION AND PREPARATION

SEED SELECTION -- The importance of using high quality seed cannot be overemphasized. Only good seed of recommended varieties should be planted. Seed of good quality has high germination, freedom from weed seeds, is practically free from cracked, shrivelled diseased seed and other crop kinds and is pure as to variety.

Farmers should only sow clean grain at seeding time. If one wishes to use his own grain for seed, home cleaning or cleaning at one of the recognized seed cleaning plants is recommended. There are many of these plants located throughout Manitoba.

Under no circumstances should grain elevators be used for seed grain cleaning as these elevators are not equipped to clean grain for seed purposes. The Soils and Crops Branch, Department of Agriculture, Province of Manitoba in a bulletin, "Manitoba Seed Grain Survey 1981", reports the statistics shown below as to grain contamination following elevator cleaning.

Seed Grades of Elevator Cleaned Grain

	% graded No. 1 seed	% graded No. 2 seed	%graded Rejected seed
1976 survey	5.9	23.3	70.8
1981 survey	9.0	20.5	69.2

The survey further indicated that 65% of the samples were contaminated with weed species and other grains not contained in the

original sample. On the basis of these results, there can be no doubt that elevator cleaning is one of the important factors in spreading weed seeds, diseased seed, and admixtures of varieties and other crop kinds.

Further evidence that underscores the importance of quality seed is contained in the findings of Manitoba Seed Grain Surveys conducted in 1955, 1965, 1976 and 1981.

Seed obtained from the grain drills of a representative sample of Manitoba farmers graded as follows:

Grade of Seed Sown	1955	1965	1976	1981
No. 1 seed	4%	13.5%	30.4%	41.9%
No. 2 seed	28%	34.5%	26.0%	26.4%
No. 3 seed	23%			
Rejected	45%	50.2%	43.6%	29.4%
Unknown				2.2%

From these survey results, it is evident that the quality of seed used in Manitoba has shown gradual improvement during the 26 year period of 1955 - 1981. The portion of No. 1 seed used has increased from 4% in 1955 to 41.9% in 1981. The use of No. 2 seed has remained fairly static, but the portion of rejected seed has dropped from 50.2% in 1965 to 29.4% in 1981. The major factor contributing to rejected seed in all years was weed seed contamination. The amount of seed cleaned in elevators dropped significantly from 36.3% in 1976, to 14.6% in 1981. A detailed write-up of the 1981 Manitoba Seed Grain Survey is available from Manitoba Agriculture.

Still other benefits to be drived from the use of high quality seed are outlined in the following section updated by J.R. Rogalsky, Soils and Crops Branch, Manitoba Agriculture.

Good Seed

Good seed is basic to good crop production. Increased yields can be obtained where high quality, well cleaned and well graded seed is used. Research has shown that large kernels retained for seed purposes will produce healthier, more vigorous plants than small

kernels; therefore, it is essential that seed be well cleaned to remove the small kernels.

Experiments conducted with barley at the Research Station, Lacombe, Alberta, proved the value of large kernels for seed purposes. In tests over a two year period and at a number of locations, the results as shown below were obtained.

The Results of Graded Seed -- Barley

	No. of seedlings	No. of Heads	Yield kg/ha
Small	392	598	2905
Medium	402	642	3336
Large	411	667	3551
Bulk	396	642	3389

Experiments conducted in Manitoba on a farm scale over a two year period with wheat further proved the superior yielding ability of well graded seed. Wheat was cleaned in the elevator and the same seed was recleaned, retaining only the largest kernels. Pedigreed seed was also used as a comparison.

Value of Well Cleaned Seed -- Kilograms per Hectare

	1966	1967	1966/1967 ave.
Elevator Cleaned	1904.5	1265.2	1581.6
Recleaned	2025.7	1292.1	1644.6
Pedigreed Seed	2025.7	1595.0	1910.7

Pedigreed Seed

Pedigreed seed of cereals, flax and forage crops is produced by members of the Canadian Seed Growers Association. This organization is not a government agency but is maintained primarily by an

assessment to all members on the basis of the area offered for pedigree status.

All crops and grain offered for pedigree are inspected by inspectors of the Plant Health and Plant Products Directorate, Agriculture Canada. Their report on the condition of the crop, isolation, weeds present, degree of varietal purity, etc., is submitted to the C.S.G.A. head office. The certificate of registration of certification is issued by the C.S.G.A. and their decision is based on the reports submitted by the Agriculture Canada inspectors.

There are five main classes of seed governed by the C.S.G.A.

1. Breeder's Seed -- This is not a seed of commerce but is the seed produced by the plant breeder. It may also be the initial seed of introduced varieties that is increased by an authorized plant breeder or institution.

2. Select Seed -- This is seed produced by select seed growers from breeder's seed. This too is not a seed of commerce but is used by the select seed grower to produce a crop of foundation seed. The select seed plot must be no larger than one hectare but may be smaller depending on the wishes and capabilities of the grower. The plot is usually planted in blocks of rows to permit cultivation and ease of roguing. The plot must be grown under strict isolation and other requirements as outlined by regulation. Before a seed grower can be accepted as a select grower he must have a number of years experience as a seed grower. His qualifications and seed growing record are carefully screened by a special committee in each province and if he is accepted he must then undertake a three year probation period before gaining final acceptance.

3. Foundation Seed -- This seed is produced by the select seed grower and is grown from select seed produced from his plot. The foundation field must be grown under strict regulations as outlined by the C.S.G.A. and the seed and field are inspected by an inspector of the Plant Health and Plant Products Directorate of Agriculture Canada. If the seed meets the required standard, a tag and seal is

attached to each bag. This seed is usually sold to other seed growers for further multiplication as pedigreed seed.

4. Registered Seed -- This class of seed is produced by a seed grower from foundation seed. It must be grown under strict conditions of isolation and land requirements as outlined by C.S.G.A. regulations, and the fields are inspected by Agriculture Canada inspectors. Seed is also inspected, tagged and sealed by inspectors of the Plant Products Directorate.

5. Certified Seed -- This is seed produced from registered seed and is the class of seed recommended to farmers who wish to purchase high quality seed for crop improvement purposes. As with foundation or registerd seed, it too must be grown under strict adherence to regulations outlined by the C.S.G.A. Seed in bags is inspected, tagged and sealed by Plant Products Directorate inspectors or may be sold by authorized establishments in bulk directly to the farmer without bagging. Only certain authorized establishments equipped with satisfactory facilities may be permitted, after inspection by an inspector of the Plant Products Diorectorate to sell certified seed in bulk. This seed must pass all the necessary quality standards that are required for bagged seed but the saving in the cost of bags is usually passed on to the purchaser.

Farmers are advised to purchase new lots of Certified seed every year, as this class of seed meets the high quality requirements of seed mentioned in paragraph one. The Canadian Wheat Board has authorized producer over-quota deliveries of commercial grain, and funds derived from this delivery may be used to purchase pedigreed seed, including bulk certified forage seeds. The sale of bulk certified seed is restricted to movement within the province concerned.

The extra cost of purchasing certified seed wheat should be more than recovered by the increase in yield obtained over the use of commercial seed.

FIELD CROPS

A. CEREAL CROPS AND FLAX

Although forage, oilseed and special crops continue to occupy increasing Manitoba cropland, the cereals still claim the major proportion of the seeded area.

The average yields of cereals and flax reflect the high native state of soil fertility during the first few decades of farming as well as the reduced yields during the drought, rust and grasshopper-ridden decades of the thirties. Trends of increasing crop yields are again noted in the all decades since the forties.

In the discussion on cereals (wheat, oats, barley, rye and triticale) and flax that follows, no attempt has been made to deal exhaustively with all the cultural practices involved in the production of these crops. Rather, priority in discussion has been allocated to areas of crop production considered of primary importance and for which recent experimental data were available. It should be noted that although much time and money has been invested into agronomic research during re-ent decades, the greater proportion of this has been absorbed in the basic kinds of studies -- studies, for example, that have assured growers of a disease or insect-resistant crop variety when they most needed it. Largely because of this pre-occupation with the natural enemies of crop production (diseases, insects, weeds) agronomists may have fallen behind in their job of periodically retesting previously established recommendations for practices such as seeding dates, rates, depths, etc. For this reason some of the recommended cropping practices have a limited amount of recent data to support them. It is not likely, however, that the technology introduced into grain production during the 1950's and 1960's will have materially altered the optimum levels of previously established farm practices such as time and rate of seeding. It is believed, therefore, that standard recommendations as presented in this section are still valid and reliable.

WHEAT

Wheat has a wide climatic and soil adaptation range. It is an important crop in climates ranging from humid to arid. In general, the more humid regions produce the softer wheats with higher yields and lower protein contents. These wheats are usually used for livestock feed or for specialized pastry, biscuit and cake flours. The hard wheats with higher protein levels are grown in areas of lower rainfall; these are the wheats that produce the "strongest" and most desirable bread-wheat flours.

The varieties of wheat that may be grown in Manitoba are severely restricted by climate. Growing season conditions usually favour the development of stem and leaf rusts on susceptible varieties. Hence, a wise choice of varieties is limited to a relatively small number of rust resistant spring wheats that are presently licensed in Canada.

Bread wheat varieties commonly grown in Manitoba require from 90 to 100 days to mature. Durum wheat varieties mature in 100 to 107 days.

Approximately five percent of the Manitoba wheat area is devoted to durum wheat. Because of the late maturity of present varieties this area is confined mainly to the southern part of the province. The market for durum wheat, while relatively small, has generally commanded a monetary premium over common wheat. Over the five crop years 1979 - 80 to 1983 - 84 this premium has averaged $6.36 per tonne. This, in conjunction with comparable yields, has given high returns per hectare. The potential durum producer looking to these higher returns, should however, carefully appraise marketability.

In recent years, the production of winter wheat has been initiated in Manitoba. The current winter wheat varieties lack sufficient winter hardiness to survive the extremely cold winter temperatures in Manitoba. For this reason, special management practices are necessary. Winter wheat must be fall planted into standing stubble which acts as a snow trap to protect the wheat seedlings through the winter months. Generally, winter wheat outyields the bread wheat varieties by 15 - 20%, but loss to rust infection poses a threat as the varieties are susceptible to stem

and leaf rust. Winter wheat is best adapted to the drier areas of the province because it makes better use of spring moisture than spring sown wheat.

Semi-dwarf wheat has recently been intoduced into Manitoba. The first Canadian variety, HY 320, was licensed in 1985. Its yield potential is about 25% above bread wheat varieties, but its protein content and baking quality is lower. A market development program for this variety has been initiated.

OATS

For best results, oats should be grown in regions with generally cool temperatures and adequate moisture. Hot, dry weather, when the crop is filling, frequently results in poorly filled kernels and low yield. For good kernel development, oats require more growing season moisture than any other small grain. For this reason oats seem to produce better when seeded in clay to clay-loam soils with good moisture retaining capacity.

Under Manitoba conditions oats require from 97 - 98 days to mature.

BARLEY

Barley is grown in more diverse climatic regions than any other crop. It is grown farther north than other crops in the Yukon and Siberia, but is also grown in the tropics. At the same time, barley is more responsive to ideal environment than any other crop. It responds quickly to fertilizer, it prefers a well-drained medium to fine-textured black or grey soil with a high pH (on the alkaline side) and it does best with adequate moisture. Too much moisture frequently results in lodging, and high humidity brings on root and leaf diseases. Barley responds well to a wide fluctuation of day and night temperatures. High temperatures will not be too injurious if humidity is not too high.

This crop is commonly grown in areas with more than 90 frost free days, although some varieties will mature in as few as 84 days.

As in wheat and oats, climate has a direct effect on grain quality. For example, most barley for malting is grown in areas of high rainfall where highest yield and starch content and lowest protein content are produced. The higher protein content feed barleys may be grown successfully in areas of somewhat lower rainfall.

TRITICALE

Triticale is a new crop species developed from a cross between wheat and rye. Its grain is much like wheat in kernel shape and color but is larger and somewhat more wrinkled. Its main use at the present time is as a livestock feed, and provided that it is free of contamination by ergot, it is equal in feeding value to wheat-barley mixtures. In addition some quantities are also being grown for milling purposes. As yet, there have been no grain grades established for triticale, thus it cannot be marketed through the normal grain marketing channels.

Triticale must be sown early. Delayed seeding adversely affects this crop more so than other cereals. It has about the same tolerance as wheat to spring frosts but is able to make a more rapid recovery because of its vigorous seedling growth. A seeding rate of 110 kg/ha has been found optimum for this crop.

The response of triticale to fertilizer is similar to that of other cereals. Moreover, the same chemical weed control as used for wheat may by used for triticale.

RYE

Fall rather than spring rye is generally grown in Manitoba. Although this crop will respond to high soil fertility and good cultural practices, it will do better than any other cereal on relatively poor soils. Sandy soils, which are unsuitable for wheat, oats, and barley, are frequently sown to rye.

FLAX

The flax crop favors growing conditions similar to those under

which wheat and barley thrive. The cool, moist climate of Canada's northern regions provides an environment for flax production ranking among the best in the world. Hot, dry conditions in mid-summer when the crop is in bloom are known to reduce crop yields as well as kernel size, weight, oil content and drying quality (iodine value).

Depending upon the season and the variety, flax varieties mature in from 88 to 97 days under normal Manitoba conditions.

Flax responds well to added nitrogen, potash, and sulphur, but shows poor response to phosphate unless it can be placed 2.5 cm below the seed or is sidebanded 2.5 cm beside and 2.5 cm below the seed. If equipment for suitable placement is lacking, growers should consider applying a heavier rate of phosphate in the year previous to growing flax, in order to gain the benefit of residual phosphate in the soils.

SEEDBED PREPARATION

Cereal Grains

Land preparation required prior to seeding varies, of course, with the condition of the land in the spring. A good seedbed is of the utmost importance in growing cereal crops. It should be firm and level so as to provide a uniform depth of seeding and a close contact between the seed and the moist particles of the soil. The method used in preparing the seedbed for any of these crops will be determined largely by the place the crops occur in the crop rotation. In all cases, however, tillage operations should be kept to a minimum.

a) After summerfallow -- a minimum of tillage is required to prepare a seedbed from fallowed land. Loosening the soil to a depth of about 8 cm immediately before seeding is a good practice. All precautions should be taken, however, to conserve the moisture that has been stored in the fallow at a considerable cost.

b) After sod-breaking -- if the sod was broken early the previous summer, the tillage requirements would be similar to those required for summerfallow. If breaking was done during late summer or fall of the previous year, one or more operations with the disk may become necessary.

c) After a cereal straw crop -- The importance of returning the straw crop to the soil after harvesting is generally recognized. If the straw is passed through a straw chopper attachment on the combine prior to spreading, no tillage problems arise. However, if spread in its whole state, straw may interfere with proper tillage, it may be poorly incorporated into the soil and may seriously reduce seed germination and seedling development the following year. If long straw becomes a problem, circular or drag harrows used when the straw is dry are effective in spreading and breaking much of the straw. Implements recommended for loosening the soil after a straw crop are listed in their order of preference:

First choice: a heavy duty cultivator with 6" to 8" shovels used lengthwise and crosswise on the field.

Second choice: a disk implement or combination of disker-cultivator.

Third choice: a mold board plow (discouraged where wind erosion is a problem).

FLAX AND CANOLA

The small size of the flax and canola kernels requires a particularly firm seedbed to ensure seed contact with the soil. Packing is best effected by the use of the cultipacker or drag harrow. Otherwise, the same practices apply as for cereals.

TIME OF SEEDING

Experiments have shown that higher yields are generally obtained when seeding is done as early in spring as the land will permit. The tables at the beginning of this section show the reduction in yields of one wheat and one barley variety when seeding (at Brandon) was delayed from early May to mid-June.

One of the biggest advantages to be gained from early seeding is when a crop variety is susceptible to prevailing diseases, like rust.

Dr. W.I. Wolfe, of the C.D.A. Research Station, Brandon, seeded Bonanza barley at weekly intervals over a six-week period beginning

about May 5 from 1973 - 1976. On the average, the best results were obtained when it was sown up to May 28. Yield fell off markedly when the crop was planted after this date. As a result a crop seeded June 19 produced a yield that was only 50% of that sown on May 5. Conquest barley did not decrease in yield with late seeding. Time of seeding affected the weight which decreased gradually as planting was delayed. Early seeding allows the crop to take greater advantage of spring moisture supplies, and gives it more time to develop before the onset of high summer temperatures.

Flax shows similar reaction to delayed seeding. Recent Manitoba experiments show that a delay from mid-May to the end of the first week in June resulted in yield losses ranging from 15 to 35 per cent. Surveys showing that over 45% of the flax in this province is sown after June 1 indicate that late seeding is much too common. Should delayed seeding be necessary due to condition of the land, weed problems, or other conditions not entirely controllable, it has been shown that choice of an early maturing variety is advisable, since such varieties generally suffer least from delayed seeding, even when fall frosts are not a factor in the result.

DEPTH OF SEEDING

Seeds should not be placed deeper than necessary to assure contact with moist soil. Although 5 cm is an average satisfactory depth for the cereals, the depth of soil moisture and the firmness of the seedbed must be considered. Seeding deeper than necessary may reduce germination and produce weaker plants. This precaution should be expecially noted when sowing small-seeded crops like flax and canola. These crops should be seeded as shallow as possible into a firm, moist seedbed. In general the moisture level is lower in lighter soils and deeper seeding is often necessary.

B. SPECIAL CROPS

1. Canola (Rapeseed)

The area of canola in Manitoba has increased dramatically in recent years. Production reached an all time high of about 546,300 hectares in 1979. Average yields have ranged from 1000 to 1250 kg/ha in recent years, although individual growers have attained yields in excess of 2200 kg/ha.

a) Varieties -- The recent changeover to low erucic acid and low glucosinolate varieties has rapidly changed the varieties being recommended. These are Altex, Andor, Regent, Westar and OAC Triton in the Argentine type, and Candle and Tobin in the Polish type. New varieties with higher oil content, better yield and earlier maturity are currently being developed. See the Current Variety Recommendations as published annually.

The Argentine types are late maturing and represent a greater risk if grown in areas with a short frost free season. OAC Triton is triazine tolerant but substantially lower yielding than the other Argentine type varieties. Candle and Tobin are early maturing but lower yielding and represents less risk in short season areas or if seeding is delayed.

b) Land Selection -- Canola does well on most soil types, but is best suited to loamy soils that will not crust too severly for the seedlings to emerge. Heavy clay and peat soils have also produced good yields.

Fields which are relatively free of wild mustard should be selected for canola production as 5% is the maximum limit of wild mustard allowed in the top three grades of rapeseed. Wild mustard can be readily controlled at a low cost in the variety OAC Triton.

Canola has a fairly high tolerance to soil salinity.

c) Seedbed Preparation -- Seedbed preparation is one of the most important factors in successful canola production. The seedbed should be firm and uniform with moisture close to the surface. Fields which are worked prior to seeding should be packed after the crop has been planted to facilitate germination and prevent excessive moisture loss.

d) Seeding Rate, Date and Depth

Rate of seeding:	Argentine type - 6 to 8 kg/ha
	Polish type - 5 to 7 kg/ha
Seed depth	2.5 cm to 4 cm
Date of seeding:	Argentine type - May 5 to May 30
	Polish type - May 5 to June 15

Canola should be sown early for uniform ripening, better grade and yield. Fall frost damage can result in serious losses through lower grades and greatly reduced returns.

A common method of seeding canola is to mix with fertilizer and seed through the fertilizer attachment. Other methods include seeding through a grass seeder attachment, or seeding through the grain seed drill seed box with newer model grain drills.

e) Disease Contro -- A crop rotation of at least four years should be used to control soil-borne diseases of canola. In localities where Alternaria Black Spot or Blackleg is prevalent, the purchase of seed from an outside area is recommended.

Avoid fababeans, field beans, field peas, lentils, mustard, soybeans and sunflowers in the rotation due to Sclerotinia stem rot. Sclerotinia stem rot may be controlled by aerial application of benomyl (Benlate) or Iprodione (Rovral) at the 20 to 30 per cent blossom stage.

Argentine types are resistant to Staghead. Do not sow canola or rapeseed adjacent to canola or rapeseed stubble, and control volunteer seedlings early in the season.

f) Insect Control -- The most troublesome insect of canola is the flea beetle. In areas where flea beetles have caused consistent economic losses to seedling canola, lindane seed treatment, Counter 5G or Furadan CR 10 granules should be used at time of seeding. For standing crops, a wide range of insecticides can be used for insect control. These include Guthion, Thiodan, Furadan, Malathion, Sevin, Supracide, and Decis.

The Bertha armyworm can cause serious losses in rapeseed. This pest can appear suddenly in scattered outbreaks. Control measures with Lannate are recommended when infestationa of over 10 - 12 worms per square meter are encountered.

g) Fertilizer -- Canola responds well to the use of fertilizer, and high rates are necessary to produce maximum yields. Phosphate fertilizer should be drilled in with the seed. Any nitrogen in excess of 7 kg/ha should be broadcast or banded to avoid seed injury.

A soil test will give specific recommendations for a particular field or farm. If the grower wishes to follow general recommendations, they may be found in a current issue of the Manitoba Field Crop Recommendations booklet.

h) Weed Control -- For current chemical weed control, consult the Guide to Chemical Weed Control, published annually by the Manitoba Department of Agriculture.

i) Harvesting -- Canola shatters very readily when ripe and should be cut when most of the pods are still green. Pods from various areas of a field should be opened to determine the correct stage of maturity for swathing by seed color. When 25% of the seeds have reached their mature color, swathing may begin. At his stage the majority of the remaining seeds may be greenish-red, and some still completely green.

The crop should be cut just below the lowest pods to minimize the amount of material in the swath. High stubble will allow the swath to settle and prevent it being blown by high winds. High stubble also permits running the pick-up below the swath, reducing the amount of shelling.

j) Dessication -- A dessicant such as diquat (Reglone) may be used to ripen standing canola. Aircraft application is required. Sixty to 75% of the seeds should be in the greenish-red to brown and/or yellow stage depending on variety, and not more than 40% should be completely green. The dessicant also kills most weeds present in the crops and speeds harvest. Check ripeness of crop carefully before applying a dessicant.

Direct combining of the Argentine type varieties is not recommended. These should be swathed three days after dessicant application. Polish type varieties may be direct combined within 14 days.

k) Storage and Drying --Canola requires a tight storage bin as the small, round seeds will flow freely through small openings. A moisture level of 10.0% is considered safe for storage, although many elevator companies prefer it to be around 8%. Harvested crops containing green weed seeds or immature canola seeds should be cleaned prior to storage to prevent heating.

The maximum air drying temperature recommended for canola is 43 degrees C for seed purposes and 54 degrees C for commercial use.

Grading Factors -- Canola is graded under provisions of the Canada Grain Act.

Grade	Max. Damaged seeds	Max. Conspicuous seeds	Max. Distinctly green seed
No. 1 Canada	3%	1%	2%
No. 2 Canada	10%	1.5%	6%
No. 3 Canada	20%	2.0%	-

Canola containing over 5% wild mustard will be graded "Sample Grade".

2. Mustard

Mustard production in Manitoba reached an all time high in 1968 when 26,000 ha were produced under contract. In recent years the planted area has declined into the range of 10,000 to 18,000 ha.

In addition to yellow mustard, both brown and Oriental are also being contracted.

a) Varieties -- Licensed varieties include Gisilba, Kirby and Ochre yellow mustard; Domo and Lethbridge 22A Oriental mustard; and a non-licensed variety of brown mustard.

These crops are generally grown under contract with the contracting agency supplying the seed.

b) Land Selection -- Mustard generally is adapted to the same soil types suitable for canola production, but is somewhat more tolerant to drought. Oriental mustard in particular has a tendency to develop a seed coat discoloration under conditions of high relative humidity and soil moisture, and is therefore best suited to the drier areas of the province.

The production of both canola and tame mustard on the same farm is not recommended. This practice could result in admixtures which can seriously degrade both crops, and cause a serious build up of diseases to which both crop are susceptible.

c) Seedbed Preparation -- Same as for canola.

d) Seeding Rate, Date, and Depth

Seeding rate -- yellow -- 8 to 11 kg/ha
brown and Oriental -- 4.5 to 7 kg/ha

Seeding date -- May 5 to May 30

Seeding depth -- 2.5 to 5 cm

Methods of seeding are the same as for canola.

e) Disease Control -- Mustard crops should be placed at least 4 years apart in the farm rotation to control soil-borne diseases.

f) Insect Control -- Recommendations for flea beetle control are the same as for canola.

g) Fertilizer -- Mustard responds well to the use of high levels of fertilizer. A soil test is the best way to obtain specific recommendations for the individual farmer. General recommendations are found in the Field Crop Recommendations booklet published annually by Manitoba Agriculture.

h) Weed Control -- For chemical weed control, consult the current Guide to Chemical Weed Control, published annually by Manitoba Agriculture.

i) Harvesting -- Yellow mustard has shattering resistance which makes straight combining possible, providing the maturity is uniform and the crop is free of green weeds. If swathing is necessary the crop should be cut fairly high. This will enable the swath to settle into the stubble and prevent it being blown by high winds. Swathing should be done when the majority of the plants are fully ripe. Brown and Oriental mustard are more prone to shattering and should be swathed under dewy conditions when the ripest pods show signs of shattering.

j) Storage and Drying -- A tight storage bin is required as mustard seeds will flow freely through small openings. The moisture content for dry mustard seed is 11%. If mechanical drying is

necessary, a maximum air temperature of 43.3 degrees C should be used for seed purposes, and 54.4 degrees C for commercial use.

k) Grading Factors -- The mustards are graded under the statutory grades established under the Canada Grain Act. Some of the grading factors for the various grades are as folllows:

	Max. % damaged seed	Max. % heated seed	Max.% distinctly green
No. 1 Canada	1.5%	0.1%	Nil
No. 2 Canada	3.0%	0.2%	1.5%
No. 3 Canada	5.0%	0.5%	3.5%
No. 4 Canada	10.0%	1.0%	3.5%

Yellow mustard may contain 0.1%, 0.2% and 0.3% wild mustard in grades No. 1, No. 2, and No. 3 respectively. No. 4 may contain a maximum of 1.0% wild mustard. If wild mustard exceeds 1%, "Sample Grade" is assigned.

3. Sunflowers

Sunflower plantings in Manitoba peaked in 1979 at 154,000 hectares. More recently plantings declined to 40,500 hectares in 1983 and 64,700 hectares in 1984. Manitoba has been the leading province for production of this crop to date.

The major portion of Manitoba's production is in the oilseed type which is crushed locally. Recently some quantities of whole seed have also been exported for crushing in the export market. Lesser quantities of the large seeded type are grown for confection purposes, and the medium sized, attractively striped type for bird feed purposes.

a) Varieties -- The current varietal recommendations are published annually and should be consulted.

b) Land Selection -- Sunflowers can be successfully produced on a fairly wide range of soil types, but are best adapted to the well-drained, medium textured soils. Due to their drought resistance they can also yield well on sandy soils. They have only moderate tolerance to soil salinity. The best yields are usually obtained on

summerfallow, but the most common practice is to grow sunflowers on stubble land. If placed on land which would normally be summerfallowed, they can be used to extend the crop rotation by 1 or more years providing good weed control practices are used.

c) Seedbed Preparation -- Sunflowers require a firm, moist seedbed. This can be best prepared by shallow spring tillage. A firm seedbed will allow for shallow planting at a uniform depth allowing for rapid and even emergence.

d) Seeding Rate, Date, and Depth --The amount of seed used per hectare will depend on the variety, and the spacing between the rows. Row spacings of 40 to 91 cm apart are the most common, but spacing of 15 and 17 cm (solid seeding) have also been used.

When planting sunflowers of the oilseed type, a final plant population of 40,000 to 49,000 plants/ha should be aimed for. This will mean a seeding rate of about 2.5 to 5 kg/ha depending on seed size used. For non-oilseed sunflowers a lower final plant population of 45,000 is desirable to ensure large seed.

If the practice of cultural weed control by harrowing after emergence of the crop is planned, the seeding rate should be increased for each anticipated operation. In a solid seeded stand, each harrowing can reduce the stand by 7,400 - 12,000 plants per hectare.

Seeding depth -- Seed should be placed in to moisture even if this means seeding to a depth of 7 to 10 cm.

Seeding dates -- All varieties should be seeded early if possible. Seedling plants are relatively frost resistant to the four leaf stage. If adverse weather necessitates delayed seeding, an early maturing hybrid or variety should be used.

Red River Valley (Zone 3, south of Township 15) - May 1 to June 5

All other regions - May 1 to May 15

e) Disease Control -- Verticillium wilt and downy mildew can be best controlled by planting resistant varieties. Since no varieties are resistant to Sclerotinia disease, follow a crop rotation of at least 5 years. Avoid fababeans, field beans, field peas, lentils, mustard, canola, rapeseed, and soybeans in the rotation to control Sclerotinia disease.

Seeds should be treated with a non-mercurial seed dressing to prevent damping-off losses.

f) Insect Control -- The sunflower beetle is the most bothersome pest in sunflowers. Both the adult and larvae of this pest defoliate sunflower crops. The sunflower beetle may be controlled by the application of Thiodan 4E at 1.4 kg (active) per ha applied in at least 4.5 litres of water per ha.

g) Fertilizer -- For specific recommendations have your soil tested. The general recommendations are listed in the current issue of the Field Crop Recommendations for Manitoba.

h) Weed Control -- Harrow operations (after planting, before and after emergence of the sunflowers) with early inter-row cultivation will usually give satisfactory control of most weeds.

Chemical -- Consult the current Guide to Chemical Weed Control, published by the Manitoba Department of Agriculture.

i) Harvesting -- Sunflower harvesting usually commences in mid-October. A sunflower header is essential to minimize harvest losses from shattering and heads dropping in front of the cutter bar. Headers are available from a number of country machine shops.

j) Storage and Drying -- For safe storage under all weather conditions, sunflowers should have a moisture content of 9.5% or less. Sunflowers with a moisture level of 12% are often stored by farmers, but this is a safe practice only during cold weather.

The maximum air temperature that is safe to use in drying sunflowers is 45 degrees C, regardless of whether for seed or commercial use.

k) Grading -- Some of the grading factors include:

Grade	Max. % Cracked of Hulled Seed	Standard of Cleanness
1 C.W.	2%	Commercially clean seed
2 C.W.	5%	Commercially clean seed
3 C.W.	10%	Commercially clean seed

4. FIELD PEAS

Field peas grown in Canada are used for the production of split and pure soup in the soup industry. Split and whole peas are also available in package form for home cooking. A large portion of Canadian grown peas are used domestically, and sizeable quantities are also exported to a number of foreign countries. Manitoba has been a major producer of field peas in Canada because our climate favors the development of a top quality product.

Field peas range from 20 to 30 per cent protein and can be used to balance low protein livestock feeds. They can replace all of the protein from a soybean-fish meal supplement satisfactorily for growing and finishing swine, providing adequate vitamins and minerals are added.

a) Varieties -- Consult your published current recommendations.

b) Land Selection -- Field peas are best adapted to well-drained clay loam soils. Poorly drained, cold soils should be avoided as they favor the development of root rotting diseases.

Field peas do not compete well with weeds and should be grown on fairly clean land. They belong to the legume family and can improve the nitrogen content of the soil, thereby extending the crop rotation.

Saline and stony soils should be avoided.

c) Seedbed Preparation -- Field peas prefer a firm and level seedbed. Early spring cultivation to seeding depth helps to warm the soil and guarantee speedy germination. This will ensure even germination and the establishment of healthy seedlings which are essential in obtaining a crop of good yield, appearance and cookability.

d) Seeding Rate, Date and Depth

Seeding Rate -- Large seeded - 170 to 200 kg/ha
Small seeded - 130 kg/ha

Seeding Date -- May 1 to May 25 -- peas will survive several degrees of frost.

Seeding Depth -- 5 to 8 cm, into moisture

e) Disease Control, Seed Treatment and Inoculation

Field peas are subject to a number of diseases. For this reason, they should be spaced a minimum of 4 years apart in the farm rotation. The use of pedigreed seed which has been disease tested is highly recommended. In addition, early seeding will help to control mildew infection which often appears in late sown crops.

The seed should be treated with a fungicide for protection against seed-borne diseases, and to reduce root rot damage. Sound, dry seed can be safely treated several weeks before planting. Most fungicides can be used to treat peas, but only Thiram or products which contain less than 30% Captan should be used if inoculation of the seed is planned.

The seed should be inoculated with a specific nitroculture for peas. The cost is small but the benefits of effective nodulation in the growing crop are readily evident. The nitroculture should be applied to the seed in the drill box immediately before seeding. Inoculated seed should be protected from direct sunlight.

f) Insect Control -- The pea aphid can cause serious damage to a rop of field peas. If aphid population becomes heavy and damage appears likely, the crop should be sprayed with 2.1 liters of malathion 50% E.C. per hectare or Dimethoate 4E at 525 ml/ha. Increased spray volume and pressure should be used to contact aphids hiding in unopened flower clusters.

g) Fertilizer --Since field peas are a legume crop the use of nitrogen fertilizer is not recommended. Phosphorus is recommended at 30 to 45 kg/ha of P205 as a sideband application. If applied with the seed the maximum rate of P205 recommended is 20 kg/ha. Sands and loamy soils are frequently low in available potassium. A soil test is recommended or apply 35 - 70 kg/ha of potash (K20). Potassium should be placed away from the seed. Twenty kg/ha sulphate sulphur is recommended on well-drained sandy soils and grey luvisol (grey wooded) soils.

h) Weed Control -- Cultural -- Peas can be effectively harrowed just before emergence to destroy weeds that may have started growing. Harrowing should be avoided during emergence and for a short period

f time following emergence. When the pea plants are at the four to six leaf stage, one or two operations of the drag harrow, rotary hoe, finger weeder, or flexible harrow will destroy many small weeds.

i) Harvesting -- Field peas may be swathed or straight combined. If swathed just prior to full mutuurity a light roller can be used behind the swather to protect the swath against wind damage. If left to full maturity, the combine should follow immediately behind the swather to avoid wind damage. The swather should be equipped with pick-up fingers.

Field peas can also be successfully straight combined if left to full maturity. Pick-up fingers or guards are necessary with this method as well.

Extreme care should be taken in harvesting field peas. Excessive amounts of foreign material, cracked seed casts, broken and damaged seeds, will result in heavy losses in the cleaning process.

j) Storage and Drying -- The moisture content of field peas should not be higher than 16% for safe storage. Peas containing green weed seeds or other foreign material should be cleaned prior to storage. Augers and grain loaders should be run at slow speeds to avoid unnecessary splitting of the peas.

In mechanical drying, a maximum air temprature of 43 degrees C should be used for seed purposes, and 70 degrees C for commercial purposes.

k) Grading Factors -- Some of the important grading factors are:

Grade	Shrivelled	Cracked Seed Casts (max.)	Splits (max.)	Other Foreign material (max.)
1 C.W.	1%	2%	About 0.5%	Trace
2 C.W.	3%	4%	About 1%	Trace
3 C.W.	5%	8%	About 1.5%	About 0.5%
Extra 4 C.W.	5%	8%	5%	About 0.5%
4 C.W.	7%	10%	5%	About 1.0%

5. LENTILS

Lentil production began in Manitoba in 1970. In recent years plantings have stabilized in the range of 10,000 to 12,000 hectares.

Lentils are a high protein crop used primarily as human food, most commonly in soups and stew. They are most widely used in European countries and South America.

a) Varieties -- Check the current published guide.

b) Land Selection -- Lentils are well adapted to Manitoba soil and climatic conditions. Generally, they mature in about 90 - 100 days. Young plants can tolerate late spring frost. Although lentils can be grown on soils ranging from sand to clay, they are best adapted to well-drained sandy loam soils. Saline and stony soils should be avoided.

c) Seedbed Preparation -- A firm smooth seedbed is important to ensure proper seeding depth. When planting on stubble land, crop residues from the previous crop must be well incorporated into the soil to provide a smooth surface. This will allow for low swathing at time of harvest. Harrowing after seeding to provide a smooth soil surface is recommended.

d) Seeding Rate, Date, and Depth

Seeding rate -- 35 to 80 kg/ha. Large seeded varieties such as Laird require a rate near the higher end of the scale.

Seeding Date -- May 1 to May 15

Seeding Depth --2.5 to 4 cm

e) Disease Control and Inoculation -- Ascochyta blight, Sclerotinia wilt, Fusarium root rot, and Rhyzoctonia root rot are the four major diseases affecting lentils. Since there are no effective treatments for these diseases, crop rotation is the most practical method of minimizing these diseases.

Follow a crop rotation of four years for control of soil-borne diseases. Avoid fababeans, field beans, field peas, mustard, canola, rapeseed, soybeans and sunflowers in the rotation because of Sclerotinia disease (white mold).

To prevent Ascochyta blight, plant only clean, non-discolored, sound seed. Have doubtful seed disease tested. Turn under crop refuse after harvest, and control volunteer seedlings.

Lentil seed should be inoculated with a specific lentil inoculum.

f) Insect Control -- Insect damage to lentil crops has seldom been noted, but cutworms and wireworms can damage the crop. Occasionally blister beetles are found in the crops, but damage has not been apparent. If serious insect damage is found, the grower should contact the nearest regional agronomist or agricultural representative for recommended insecticides.

g) Fertilizer -- For specific recommendations, the soil should be tested. Because lentils are a legume, nitrogen is not recommended. For further general recommendations, consult the Field Crop Recommendations booklet.

h) Weed Control -- Lentils are poor competitors with weeds. Weed control is therefore essential for successful production of this crop.

Harrowing just prior to emergence will help to control annual weeds. Following emergence of the crop, a coil spring harrow can be used when the lentils plants are 7 to 10 cm in height. Harrowing on a hot dry day destroys the largest number of seedling weeds and causes least damage to the lentil plants. Some loss of lentil plants can be expected from post-emergent harrowing. Horrowing should be avoided in damp weather or when dew is present to minimize the spread of disease.

For recommended herbicides, see the annual Guide to Chemical Weed Control.

i) Harvesting -- Lentils should be swathed when the plants begin to turn yellow, and the lower pods become yellowish brown to brown in color.

Swathing should be undertaken when there is sufficient dew to toughen the lower pods, and minimize shattering. A pick-up reel and lifter guards are very helpful in windrowing. A floating cutterbar can further minimize windrowing losses and operational difficulties.

Lentils are considered dry at 14% moisture content. Combining at or below this moisture level can result in high pick-up losses and damaged seed. It is therefore advisable to combine at higher a moisture content of 18 - 20% and dry artificially.

If uniformly mature, it may be possible to straight combine

lentils at a moisture level of 18 - 20%. The combine should be equipped with a floating cutterbar to minimize header losses.

j) Storage and Drying -- The moisture level of lentils should not be higher than 14% for safe storage. If harvested at higher levels they can be successfully dried in heated air dryers. The maximum air temperature should not exceed 43 degrees C. An alternate method is natural air drying which will eliminate stress cracks, minimize handling, and requires less supervision.

k) Grading Factors

Grade	Max. Heated	Maximum Peeled Split and Broken	Max. Other Damaged	Total Damaged	Foreign Material Stones	Foreign Material Total Including Stones
No. 1	0.2%	2%	1%	2%	0.1%	0.2%
No. 2	0.5%	3.5%	2%	3.5%	0.2%	0.5%
No. 3	1%	10%	10%	10%	0.2%	1%

6. FABABEANS

Commercial production of fababeans began in Manitoba in 1972. Plantings expanded to 8,800 hectares in 1980, but then declined to an average of about 4,800 hectares in more recent years.

The seed protein content of fababeans ranges from 28 to 31%. They can be fed successfully to all classes of livestock and poultry and can replace soybean meal in most rations.

Fababeans can also be grown for the purpose of ensilage. Silage made from whole plant fababeans is an excellent source of protein and carotene and has a fairly high energy content. Fababean silage can be used in many rations for cattle and sheep.

a) Varieties -- Check the current list of recommended varieties published annually. The average maturity ranges from 101 to 106 days.

b) Land Selection -- Fababeans grow best under cool, moist conditions. They require a good moisture supply for optimum yield, and are ideally suited for production on heavier soils with good water retention capacity. Most frequently fababeans are grown on

well prepared cereal crop stubble.

c) Seedbed Preparation -- Stubble fields that have been well prepared through fall tillage, usually require only a single spring tillage operation to prepare a suitable seedbed. The depth of spring tillage should not exceed the intended depth of planting. This operation should be undertaken in early spring to help warm the soil and facilitate speedy germination.

d) Seeding Rate, Date, and Depth

Seeding Rate - 135 to 200 kg/ha (large seeded varieties require the higher rates.)

Seeding Date - April 25 to May 15 (fababeans have a good tolerance to frost in seedling stage)

Seeding Depth - 6 to 10 cm (fababeans must be in contact with moisture until well established)

e) Disease Control and Inoculation -- Fababeans are subject to a number of diseases which attack other broadleaved crops. The use of seed known to be free of Ascochyta is recommended to avoid losses from seed borne Ascochya blight. Follow a crop rotation of at least four years between successive srops of fababeans to control Ascochyta and other soil born diseases. Due to Sclerotinia disease, field beans, field peas, lentils, mustard, canola, rapeseed, soybeans, and sunflowers should be avoided in the rotation.

Fababeans should be inoculated with a specific inoculum to promote nitrogen fixation. For best results, the inoculum should be slurried on the seed in a mixer just before seeding. The inoculated seed should not be exposed to direct sunlight.

f) Insect Control -- No serious insect damage to fababeans has been reported. Blister beetles pose the largest threat but seldom have to be controlled. Other insects causing minimal damage include grasshoppers, cutworms and aphids. If damage appears, the farmer should contact the regional agronomist or agricultural representative for recommended insecticides.

g) Fertilizer -- A soil test is necessary to provide accurate fertilizer recommendations. Because it is a legume, nitrogen is specifically not recommended. For other general recommendations,

check the annual Field Crop Recommendation guide.

h) Weed Control -- Fababeans are poor competitors with weeds, particularly in the seedling stage. This makes weed control essential for successful production.

Growers should consult the annual "Guide to Chemical Weed Control" for latest recommendations.

Cultural weed control should be used only if chemical control fails. In mellow soils the coil spring or diamond harrow may be used to destroy annual weed seedling when the fababean plants are 5 to 15 cm in height. Harrowing on a hot, dry day destroys the largest number of weeds and causes least damage to fababean plants. Harrowing should be avoided in damp weather or when dew is present to prevent the spread of disease.

i) Harvesting -- Swathing should begin when the lowest two pods begin blackening. At this stage the moisture content of the beans will be in the range of 35 to 45%. The high moisture content requires a fairly long drying period in the swath, so it is advisable to lay a fairly light swath. In heavy stands this means using only a partial cut if a large swather is used.

In combining, low cylinder speeds of 300 - 500 r.p.m. should be used to minimize bean splitting and cracking.

j) Storage and Drying -- The maximum moisture content for safe storage of fababeans is 16%. If mechanical drying is necessary a maximum temperature of 30 to 40 degrees C should be used to avoid stress cracks. If the beans are intended for on-farm feeding, temperatures in excess of 40 degrees C may be used.

k) Grading Factors

	Foreign Material		Maximum Limits	
Grade Name	Stones or Shale	Total Foreign	Damaged	Sulits
No. 1 Canada	0.05%	0.1%	2%	3%
No. 2 Canada	0.1%	0.2%	4%	6%
No. 3 Canada	0.2%	0.5%	6%	9%
No. 4 Canada	0.5%	1%	10%	12%

7. CANARYSEED

Canaryseed is used as a food for caged and wild birds. It is usually the main component in bird food mixtures, in combination with millet, buckwheat, and sunflower seeds.

Production of canaryseed began in Manitoba in 1957. Plantings of this crop reached 20,600 hectares in 1982, but usually fall into the range of 10,000 to 15,000 hectares.

a) Varieties -- The varieties Alden and Keet are recommended in Manitoba. Keet has displayed a small yield advantage over Alden. Both varieties mature in Manitoba in about 96 days, and are very similar in plant height and seed size.

b) Land Selection -- Canaryseed is well adapted to moist soil types in Manitoba. Due to its shallow root system, canaryseed requires favorable moisture conditions to yield well. Sandy soils will produce only marginal yields in years of low rainfall and high temperatures. Growers have found canaryseed to be somewhat more tolerant to saline soils than wheat.

Summerfallow fields have provided the highest yields. Well prepared stubble fields which are reasonably free of weeds have also provided satisfactory results. Fields in which Treflan was applied in the previous year should be avoided as canaryseed is very susceptible to this chemical.

c) Seedbed Preparation -- A firm seedbed is important to ensure proper seeding depth. Spring tillage should consist of a single, shallow operation to control emerged seedling weeds and help warm the soil.

d) Seeding Rate, Date and Depth

Seeding Rate - 40 kg/ha (for discer seeding increase by 20%)
Seeding Date - preferably in early May
Seeding Depth - 3.5 to 5 cm

e) Disease Control -- Very few disease problems have been reported in canaryseed production in Manitoba.

f) Insect Control -- Insect pests have not been a problem in canaryseed production to-date. Aphids are frequently found in this crop but economic damage occurs only if heavy infestations are present during the early stages of seed development.

g) Fertilizer -- The fertility of needs of canaryseed should be determined by soil test. If soil analysis results are not available, the higher rates recommended for cereal crops in the general fertilizer recommendations may be used.

h) Weed Control -- Canaryseed does not compete well with weeds. This means that effective weed control is essential for successful production.

The following herbicides have recently been registered for postemergence application in canaryseed:

Wild oat control: Avenge 200C, Matavan

Broadleaf weeds and certain volunteer crops: Brominal M, Bromox 450M. Buctril M, Sabre, Banvel and MCPA, Pardner, Torch, Torch DS, and Stampede CM.

i) Harvesting -- Canaryseed should be allowed to reach full maturity before harvesting. Since the crop is resistant to shattering, straight combining is recommended. If swathing is preferred, the crop should be cut at the same stage of maturity as for straight combining.

j) Storage -- For safe storage, the moisture level of canaryseed should not exceed 12%.

k) Grading Factors -- There are no established grades for canaryseed seed. It is usually sold on a cleaned basis at 99.5% purity. Dehulled seed is considered as dockage, and in combining should not exceed 3%.

8. BUCKWHEAT

Manitoba is the leading producer of buckwheat in Canada. Annual production in Manitoba has ranged from 50,600 hectares in 1981 to 32,400 hectares in 1984.

Buckwheat grain is used primarily for human consumption. The bulk of local production is exported to many countries with Japan being the best customer. The Japanese use buckwheat flour in making noodles, a traditional food. They also use the hulls for stuffing pillows.

a) Varieties -- The varieties Mancan, Manor, and Tokyo are presently the only varieties recommended. Manor is the latest variety licensed for sale in Canada. The Japanese market prefers Mancan and Manor due to large seed size.

b) Land Selection -- Buckwheat will grow under a wider range of soil conditions than any other grain crop. However, it is best suited to slightly acid, well drained sandy loams. It does not produce well on heavy, poorly drained land, or on sandy soil subject to extreme drought.

c) Seedbed Preparation -- Buckwheat is often grown on poorly prepared land but best results are obtained on well prepared soil. Since buckwheat is usually seeded late, it is possible to obtain a good kill of weeds prior to planting. After spring cultivation the field should be harrowed to leave a firm level seedbed.

d) Seeding Rate, Date and Depth

Seeding Date - June 1 to June 25. Since buckwheat is extremely susceptible to frost, seeding must be delayed until the danger of a late spring frost is passed.

Seeding Rate - 40 to 55 kg/ha

Seeding Depth - 4 to6 cm

e) Disease and Insect Control -- No serious disease or insect problems have been encountered with this crop.

f) Fertilizer -- The fertility requirements of buckwheat are similar to those of cereal crops. General recommendations may be found in the current issue of the Field Crop Recommendations guide.

g) Weed Control -- Consult Guide to Chemical Weed Control for chemicals currently registered for weed control in buckwheat.

h) Harvesting -- Buckwheat is usually swathed when about 75 per cent of the seeds are brown. Since ripening is rarely uniform, some green seeds or even blossoms are present when the crop is swathed. Sometimes buckwheat is harvested prematurely to avoid frost damage, and ripening continues in the swath. If heavy frost occurs, the crop should be swathed immediately as severe lodging will take place within a short period of time. If the crop matures to a point at

which shattering begins, swathing should be done when dew is present, or under damp weather conditions.

i) Storage -- Buckwheat can be safely stored at a moisture level of 16%.

j) Grading -- Some of the grading factors include:

Grade	Max. Foreign Material Other than Grain	Other Grains
1 C.W.	Practically Free	1%
2 C.W.	1%	2.5%
3 C.W.	2%	5%

9. CORN

Corn for both grain and silage production has been grown in Manitoba for many years. Grain corn is used for distilling purposes and livestock feeding. Silage corn, involving the use of the whole plant, makes an excellent high energy feed for beef and dairy cattle.

Manitoba currently has an annual market for about 45,00 tonnes of high quality grain corn for distilling purposes. The balance of production usually finds a ready market in the western Canadian feed industry. In 1984 about 73,000 hectares of grain corn were grown in Manitoba. This produced enough high quality corn to satisfy about 55% of the western Canadian market. The remaining quantity is being imported from the United States.

Climate is a very important factor in Manitoba corn production. The earliest hybrid varieties currently recommended have a heat unit rating of 2150 corn heat units. This means that grain corn production should be considered in only those areas of the province that receive a minimum of 2200 corn heat units. Since silage corn is harvested before full maturity, the heat unit requirement is 200 units lower than for grain corn. For this reason, hybrids requiring 200 heat units more than the rating for an area can be used in silage production, e.g. a 2400 heat unit hybrid may be used in a 2200 corn heat unit area.

According to climatic studies recently conducted the corn heat units accumulated in Southern Manitoba vary between 2000 and 2500.

The highest accumulation occurs in the Pembina Triangle and Portage la Prairie area of Manitoba which are characterized by 2400 - 2500 heat units. In general, the risk factor for successful grain corn production increases with increased distances from these central locations, except for small areas such as the extreme southwestern part of Manitoba where local climatic conditions are also favorable. From a heat unit standpoint, silage corn can be successfully produced in all areas of southern Manitoba.

a) Varieties --- Early maturity should be the main criterion for selecting a hybrid except in the most favorable growing area (southern portion of Zone 3) where other characteristics should also receive major consideration.

The varieties recommended for both grain and silage production are listed in order of maturity in the annual Field Crop Recommendations.

b) Adaption and Land Selection -- Field corn for grain is adapted to the light and medium sandy loam soils of crop zones 3 and 1. Zone 1 as well as the northern portion of Zone 3, is somewhat riskier than the southern portion of Zone 3.

Field corn for silage is adapted to the light and medium sandy loam soils of the southern prairies. In the more northern areas the risk is somewhat greater.

Corn should not be grown on soils that are either poorly drained or saline.

c) Seedbed Preparation -- Corn seed requires a soil that is warm, moist, and only fine enough to give contact between the seed and soil. Over-working the field in spring is not only expensive, but may cause excessive loss of moisture through evaporation. In general, soils that have been fall tilled can be prepared with a single shallow cultivation and harrowing in the spring.

d) Seeding Rate, Date and Depth -- The desired plant population varies with the soil type, fertilizer applied, and whether the crop is for grain or silage production. On very light sandy soils which are prone to moisture shortage, a lower plant population is recommended. On heavier soils with better moisture retention

capacity, plant population should be 45,000 - 60,000 plants/ha for grain, and 55,000 to 70,000 plants/ha for silage purposes. In order to insure the desired plant population, overplanting by 15% is recommended.

Seed spacing necessary to give the Required Plant Population Assuming an 85% Plant Survival.

Row Width	Plants per ha 45,000	Plants per ha 49,000	Plants per ha 55,000	Plants per ha 60,000	Plants per ha 69,000
cm	cm	cm	cm	cm	cm
76	25	23	20	19	16
91	21	19	17	15	14
97	20	18	16	15	13
102	19	17	15	14	12

The recommended planting dates are May 1 to May 15. Later planting results in lower yields and quality. Planting later than May 25 for grain and June 5 for silage is not recommended.

The recommended planting depth is 2.5 to 5 cm depending on moisture conditions.

Row spacing -- 75 to 100 cm depending on planting and harvesting equipment.

e) The main disease of economic importance is stalk rot. It may cause economic loss because the diseased plants break over before harvest and are therefore lost. Organisms causing this disease are present in all soils. During periods of severe stress caused by drought, prolonged cool weather, etc., stalk rot may flare up. There is no practical means of control of this disease. Breeders are striving to develop varieties with resistance to stalk rot.

f) Insect Control -- The European Corn Borer has been very prevalent in recent years. It can be controlled with several applications of a suitable insecticide. The main damage caused by the corn borer is that it weakens the stalk and causes corn plants to break over.

Wireworms and Root Maggots have been noted in some areas of Manitoba. A seed treatment such as DCL (diazinon, captan, lindane) is recommended for control.

g) Fertilizer -- Corn is usually planted on stubble land that is low in fertility and responds well to applications of nitrogen and phosphorus. The amount of fertilizer to be added will depend on the fertility of the soil and the intended plant population (a higher population requires more nutrients than a lower population).

A soil test to determine the specific fertility requirements of a field to be planted is highly recommended. General recommendations may be found in a current issue of the Field Crop Recommendations.

h) Weed Control -- Cultural methods of weed control include the rotary finger weeder and spike tooth harrow, which can be used until the corn is 15 cm in height. After emergence of the corn plants these implements should be used on bright, warm days as the young corn plants are less likely to be injured when slightly wilted. Inter-row cultivation should be started early and may continue until the corn plants are 75 cm tall. Cultivating too deep or too close to the corn plants can prune the roots and cause serious damage.

For details on chemical weed control see the Guide to Chemical Weed Control, published annually by the Manitoba Department of Agriculture.

i) Harvesting -- Grain corn is usually harvested with a self-propelled combine equipped with a special corn header. Harvest may begin when the kernel moisture is 25 - 30%. The corn must then be mechanically dried for storage purposes.

Silage corn should be harvested when the moisture content of the entire plant is 65 to 70%. At this stage the kernels should be well dented and have a glazed appearance. A light frost that wilts the leaves will not lower the feeding value of the corn crop. The maturity of the ear is very important as it contributes about 70% of the feeding value of the corn silage.

j) Storage and Drying -- All grain corn must be dried to 15% moisture or less for safe storage. The maximum air temperature recommended for drying corn for seed purposes is 43 degrees C, while

corn for commercial use may be dried at 54 degrees C. A higher temperature of 82 degrees C may be used for corn intended for animal feeding purposes.

k) Grading -- The corn quality specifications for distilling purposes are as follows:

A. Maximum moisture content - 15%

B. Maximum limits of damaged corn

1. Head damaged - 0.1%
2. Total damaged - 3%

C. Maximum cracked and foreign material - 2%

D. Odor

1. Corn must be free of any burnt and noxious odors.
2. Oil-dried corn will not be accepted.
3. Propane or natural gas fired dryers are recommended.

E.

Grade	Minimum Kilograms per Measured Hectolitre
1 C.W.	68
2 C.W.	66
3 C.W.	64
4 C.W.	62
5 C.W.	58

VIII. HOW VARIETY RECOMMENDATIONS ARE MADE

Recommendations as to the best crop varieties for the various crop zones of Manitoba are made annually on the basis of variety performance data in each of the eight crop zones. Additional agronomic and disease data are provided by the Western Canadian Co-op tests, administered by Agriculture Canada Research Branch.

During the period of 1979 -1985 the zonation testing program was conducted by the Department of Plant Science, University of Manitoba, under the Agro-Man agreement funded jointly by Agriculture Canada and Manitoba Agriculture. The Department of Plant Science conducted tests at 12 locations. In addition Western Canada Co-op tests were conducted at several locations by Agriculture Canada Research Stations.

The varieties which enter the tests are selected annually and include those already recommended for production in the province together with unlicensed varieties or lines which show promise under Manitoba conditions.

The provision of crop variety recommendations is a responsibility of the Crop Science Lead Committee of the Manitoba Agricultural Services Co-ordinating Committee (MASCC). The various sub-committees under the Crop Science Lead Committee provide the necessary expertise, review the data and propose variety recommendations on cereal, oilseed, special, and forage crops. These recommendations are discussed, ratified, or rejected at the annual meeting of the Crop Science Lead Committee at which all members of the sub-committees are expected attend. The final crop variety recommendations are printed annually in the Field Crop Recommendations for Manitoba.

In past years the Agronomy Conference assumed the responsibilty of variety recommendations. The Conference now functions as a forum for agricultural scientists, extension workers. and farmers to participate in an exchange of information.

Some Manitoba farmers who have introduced and seeded crop varieties from the United States, or from other provinces, have in a

number of ways paid dearly for their folly. In some cases varieties that performed will elsewhere were found to be highly rust susceptible and hence were virtually destroyed by the disease when seeded in this province. When offering inferior varieties for sale, other growers have suffered drastic reductions in grain grades and in some cases these varieties have not been purchased by the agents of the Wheat Board (Country Elevators) when offered for sale.

Because disease resistance is one of the main requirements of all cereal varieties, the variety recommendations change at least as frequently as do crop diseases. New rust races may emerge at any time and render hitherto resistant varieties susceptible.

VIII. WEED CONTROL*

Weeds are considered the most important limiting factor in crop production. Through competition for light, soil moisture, mineral nutrients and other growth factors, weeds reduce the yield and quality of grain, hay, pasture, vegetable and oil seed crops. Additional machines for cultural and chemical control practices, for harvesting crops and for grain cleaning are needed to combat the weed problem. Weeds harbor insects and plant diseases which can and often do serious damage to commercial crops.

A. Characteristics of Weeds

A thorough knowledge of the habits or characteristics of each weed species is essential to the development of a sound weed control program on the farm. Some of the relevant characteristics will be discussed here.

Life Cycles of Weeds -- Annuals are weeds which complete their life cycles in less than 12 months. There are two types: Summer annuals which germinate in the spring, produce seed during summer or autumn and die with the first fall frost (ex. wild oats,

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*Copied directly from "Principles and Practices of Commercial Farming" published by the Faculty of Agriculture, University of Manitoba.

wild mustard, wild buckwheat, green foxtail, Russian thistle, kochia etc.). Winter annuals germinate in the fall, produce a rosette type of growth which overwinter, flower the following spring and produce seed in the late spring or early summer (ex. stinkweed, shepherd's purse, blue burr, chickweed, etc.). Both types spread primarily from seed. The main objective in attempting to control annual weeds is to promote seed germination and then destroy the seedlings. Germination can be promoted by timely cultivation, adding organic matter to the soil, and moisture conservation practices. The optimum time to destroy seedlings is during early growth stages before secondary roots have developed.

Biennials are weeds which live for more than 12 months but less than 24 months. They germinate in the spring or early summer and produce leafy vegetative growth and a tap root during the first year. In the second year they develop stalks on which are found the flowers and seeds (ex. sweet clover, common burdock, tansy mustard, poison hemlock, etc.). Like annuals, they spread primarily from seed, although root pieces, if transported to other areas, can start a new infestation. Biennial weeds are readily controlled on cultivated land by thorough fall and spring tillage practices.

Perennials are weeds which live for more than two years and which may persist indefinitely unless steps are taken to destroy them. Perennial weeds spread vegetatively as well as from seed. They are classified on the basis of their vegetative mode of reproduction. Creeping perennials spread by means of spreading rootstalks, (ex. Canada thistle, leafy spurge, toadflax, etc.), rhizomes or underground stems (quack grass) or stolens (ground ivy). Simple perennials reproduce from tap roots (dandelion), fibrous roots (foxtail barley), bulb (wild onion), tubers (nutgrass), or corms, (death camas).

The objective in controlling perennial weeds is two fold. First, seed production must be prevented by mowing, spraying or tillage, and second, the food reserves in the roots or other underground storage organs must be depleted. The latter can only be done by frequent and thorough defoliation or regrowth by repeated cultivation,

spraying, or both. The starvation of root systems in deep rooted perennial weeds is one of the most challenging problems a farmer is likely to face in weed control.

Weed Seed Production -- Weeds are, in general, very prolific seed producers. Although the number of seeds produced per plant varies with growing conditions and genetic factors, a few examples will be cited. One plant of wild oats will produce about 250 seeds, one plant of wild mustard from 10,000 to 20,000 seeds, while over 200,000 seeds have been counted on a single plant of redroot pigweed. Preventing seed production in a weed control program is, therefore, of utmost importance.

Weed Seed Dissemination -- Weed seeds can travel considerable distances even without the aid of man. Natural agents contributing to the spread of weed seeds are wind, water, animals and birds.

Wind is very important in weed seed movement as many weeds have special adaptations which render them susceptible to wind dispersal. The tumbleweeds, for example, have rounded contours which facilitates movement by wind. Other weeds have special appendages on the seeds themselves (winged margins, long silky hairs, spreading tufts of hair, etc.), which enables them to move readily in even a light breeze. Small round seeds can be carried along by drifting soil or snow while the minute spores of other weeds can be carried hundreds of miles by wind.

Water, from spring runoff, in drainage ditches, creeks and rivers, carries many weed seeds. Some weed seeds have special appendages (air sacs or corky layers), to help them float in water. Small, light seeds will float due to the surface tension of water but will sink when the water is agitated. Others float because of hairy appendages attached to the seed. New infestations are often found at the high water mark of spring flooding.

Both wild and domesticated animals are responsible for scattering weed seeds. Some weed seeds, because of awns, spines or burrs are well adapted to cling to the hair, wool or skin of animals, only to be discarded at some other location. Most weed seeds can pass through the digestive tract of animals with their viability

unimpaired. Rodents gather weed seeds for food and most animals carry weed seeds in the mud of their feet. Weeds with fleshy fruits are very attractive to birds, which, after devouring the fleshy fruit, discard the unharmed seed.

B. Weed Control Methods

Weed control can be defined as sufficient suppression or killing of weeds to permit a satisfactory farming practice. Weed eradication, on the other hand, refers to complete elimination of weeds or a weed species from a specified area. Complete elimination is difficult, expensive and only attempted under certain conditions.

The first step in developing a sound weed control program on the farm is to prevent the introduction and spread of new weed species. The following steps or precautions will insure against new weed infestations arising:

1. Sow only clean seed.
2. Use clean feed grains and fodder.
3. Clean machinery before moving from one area to another.
4. Weed control along roadsides, headlands and drainage ditches.
5. Exercise care in the disposal of screenings.
6. Cover truck or wagonboxes when transporting grain.
7. Maintain a close watch over fields during the growing season, and have unknown plants identified.

C. The Manitoba Noxious Weed Act

Every responsible citizen of Manitoba should be familiar with the provisions of the Noxious Weed Act. The Act lays down the principle that the individual land owner, whether person, company or other, is responsible for the destruction of any weed listed under the act as noxious as often as is necessary to prevent the production of seed. Land owners are also responsible, in rural area, for that portion of any road allowance which adjoins their property, from the property line to the middle of the road. In urban areas, the municipality assumes responsibility for roads, streets, lanes and boulevards.

Authority for the enforcement of the act is the responsibility of the municipality. This authority may be assumed by the Provincial Government only be a decree of the Minister of Agriculture if and when the municipal authority fails to carry out its responsibilities.

For the enforcement of the law, municipal councils are required annually to appoint weed inspectors and to advise the province of the appointment not later than March 1 of each year. The inspector is empowered with free access to any and all lands under his jurisdiction, empowered to compel compliance with the act under penalty of fine and empowered to take necessary action for the destruction of the weeds where compliance does not occur. The costs of such actions may be charged to the owner concerned by placing the charges on the tax roll.

The municipal council may levy monetary penalties on a yearly basis against land owners who, in there opinion, fail to carry out satisfactory weed control, and may take over land, in order to carry out a program of weed eradication. The cost of the eradication program may be charged against the property.

Other requirements of the Act deal with the safe handling of weed seeds, or material containing such, with the movement of machinery or other things containing or carrying weed seeds, and with many other factors which have a bearing on the potential movement of weeds from one area to another.

Because new chemicals to control weeds are continuously being developed and because new techniques evolve, it is necessary to publish chemical weed control methods annually. The student is referred to the current issue of "Guide to Chemical Weed Control" published by the Manitoba Department of Agriculture.

IX. FORAGE CROPS

Definition

Forage crops are those plants which are grazed by animals (pasture) or harvested by man as soiling, silage or hay crops. Included in forage crops are the native grasses and legumes, tame or seeded perennial grasses and legumes, annual crops such as cereals and corn and all other annual or perennial plants which are grazed or fed in a relatively unaltered form.

I. VALUE OF FORAGE CROPS

It is difficult to put a precise value on forage crops to the province or to the individual farmer; however, the following benefits should be recognized:

--Forages provide feed for livestock. In Manitoba grasses and legumes supply the bulk (on average 85 %) of feed for the ruminant livestock population. Better forage management is one of the key factors in increasing efficiency of production and/or livestock numbers in Manitoba.

--Forage crops in permanent stands or in rotation provide a measure of soil erosion control on cultivated land. The leaves and stems of forage crops provide an excellent canopy for the interception of rain; the extensive root system holds the soil thus preventing runoff or wind erosion damage while at the same time improving water transport through the soil.

--Forage crops, properly managed, will improve the tilth and organic matter content of soils. Inoculated legumes worked in as green manure crops will add nitrogen to the soil. The amount added varies with the crop, soil, effectiveness of nodulation and the environment but could exceed 120 kg. per hectare.

--Forages are adapted to a wide range of soil types and may be grown at a competitive advantage on some soils. Although the highest yields of forages are obtained on our best soils, some forages produce higher returns than do cereals on saline soils, on areas

subject to flooding and on areas where cultivation may be difficult or undesirable due to topography, stones or similar factors.

--Forages permit diversification; although forages are grown primarily for feed, some forages may be grown profitably for seed. Currently forage seed production in Manitoba is a 10 million dollar business which could be expanded.

The benefits commonly associated with forage crops can be realized only if these crops are given management comparable to that given to annual cash crops. Most varieties of our recommended forage grasses and legumes have the potential to produce from 5,000 - 11,000 kg. of dry matter per hectare given reasonable management. Unfortunately, many of our native and tame hay stands are producing, respectively 1,000 - 4,000 kg. of dry matter per hectare. Such stands are not economically competitive with other crops; they produce relatively little forage and do little to improve the tilth or nitrogen and organic matter accumulation in the soil.

II. CHOOSING A FORAGE CROP

The choice of crop is influenced by the purpose for which the crop is required, the rotation used, soil and climatic conditions and market demand.

GRASSES

The grasses recommended for Manitoba are listed below:

		Seeding Rate kg/ha	Seeding Rate lb/ac	Time to harvest	
Crop	Uses	Hay	Seed	Hay	Seed
A. All soils except where drainage is poor					
Bromegrass	P, H, S*	8(7)	3(3)	early heading	**
Intermed. Wheatgr.	P, H, S	8(7)	4(4)	early heading	**
Russian Wild Rye	Seed		7(6)		**
Slender Wheatgrass	Seed		6(5)		**
Tall Wheatgrass	Seed		9(8)		**

B. Soils with ample moisture, good drainage					
Creeping Red Fescue	Pasture	4(4)			
Meadow Fescue	Pasture, Seed	6(5)	3(3)		**
Orchardgrass	Hay, Pasture	7(6)		early heading	**
Timothy	P, H, S	2(2)	2(2)	early heading	**
C. Lignt soils and areas deficient in moisture					
Crested Wheatgrass	P, H, S	8(7)	3(3)	early heading	**
Russian Wild Rye	Pasture	9(8)			
D. Poorly drained areas subject to temporary flooding					
Reed Canarygrass	P, H, S	7(6)	4(4)	early heading	**
Timothy	P, H, S	2(2)	2(2)	early heading	**

Crop	Uses	Hay	Seed	Hay	Seed
E. Saline Soils					
Russian Wild Rye	Pasture	9(8)			
Slender Wheatgrass	Hay	9(8)		early heading	
Tall Wheatgrass	Hay	11(10)		early heading	

F. Organic soils

Grow winter-hardy grasses -- bluegrass, bromegrass, creeping red fescue, intermediate wheatgrass, reed canarygrass, slender wheatgrass, and timothy.

* P, H, S -- pasture, hay and seed

** Swath when first heads are beginning to shell.

A brief description of these grasses and the recommended varieties of these grasses follows:

Smooth Bromegrass

This is a tall, leafy long-lived hay type grass. It is moderately resistant to drought and to flooding and moderately tolerant to salinity. Brome produces underground stems (rhyzomes)

which allow the crop to be competitive with other species but which eventually (3-5 years) lead to a sodbound condition which decreases yield. Disease and insect pests are not usually a problem. Palatability is good.

Brome varieties are two basic types:

Southern type--upright, less leafy, more disease resistant, low seed yield in Manitoba.

Northern type--less upright, more leafy, good seed yields in Manitoba.

kg. / ha.

Varieties	Type	Forage St. Claude	Seed Arborg
Baylor	Southern	8135	730
Beacon	Southern	7996	595
Blair	Southern	7246	557
Carlton	Northern	8292	610
Magna	Intermediate	7238	669

Crested Wheatgrass

A long-lived bunchgrass with fine stems and narrow leaves. It possesses excellent resistance to drought, fair resistance to flooding and moderately tolerant of salinity. Spring growth commences early; palatability initially is excellent but decreases quickly as seed stems mature. Competitive ability is good and disease and insect pests are minimal. Two types of crested wheatgrass are recognized:

cristatum type--diploid, short, fine-stemmed, small seeds

desertorum type--tetraploid, taller, coarser, large seeds

The recommended varieties are shown below:

kg. / ha.

Variety	Type	Forage St. Claude	Seed Arborg
Fairway	cristatum	8838	885
Parkway	cristatum	9173	948
Nordan	desertorum	8399	974

Intermediate Wheatgrass

A tall, moderately creeping rooted, short-lived (3-4 years) grass. Drought, flood and salinity tolerance are rated fair to poor. Competitive ability is only fair. Forage yields and palatability are good.

The recommended variety of intermediate wheatgrass is:

Chief--A persistent variety producing high yields of dry matter (7000 kg/ha) or seed (670 kg/ha).

Meadow Fescue

A cool-season, short-lived, bunchgrass which grows best on fertile, moist soils. It is best suited for pastures as palatability decreases rapidly with maturity. It is a high yielding seed crop.

The recommended varieties of meadow fescue are shown below:

kg. / ha.

Variety	Characteristic	Forage St. Claude	Seed Arborg
Ensign	tall, early	5511	727
Trader	later, rust res't	5360	544

Russian Wild Ryegrass

A long-lived bunchgrass producing numerous 25-50 cm basal leaves. Competitive ability is poor in seedling stage, but excellent in established stands. Drought resistance is excellent and salinity tolerance is also excellent when established. This grass is the first to start growth in the spring and continues to grow until late fall. Palatability is moderately good at all stages of growth.

The recommended variety is:

Sawki--high dry matter (4500 kg/ha) and seed yields (432 kg/ha); drought resistant and salt tolerant.

Slender Wheatgrass

A short-lived (3-5 years) bunchgrass which produces good yields of fairly palatable hay. Seedlings are easily established and

competitive. Drought resistance is good and salinity tolerance is high. Flood tolerance is moderate.

The recommended variety is:

Revenue--leafy, high dry matter digestibility. Forage yield --5130 kg/ha; seed yield --525 kg/ha.

Tall Wheatgrass

A tall, coarse non-creeping grass valued primarily for salinity tolerance. Palatability is fair prior to full bloom and decreases rapidly as the plant matures. Poor drought resistance.

The recommended variety is:

Orbit--Superior winterhardiness; withstands 3-4 weeks of spring flooding. Forage yield -- 5700 kg/ha; seed yield -- 1267 kg/ha.

Timothy

A moisture-loving, drought susceptible, long-live bunchgrass, which produces fair quality hay. Flood tolerance is fair to good; salinity tolerance very low. Timothy is a popular seed crop; many cultivars of European or Asiatic origin are grown under contract.

The recommended varieties are:

		kg. /ha.	
		Forage	Seed
Variety	Type	St. Claude	[illegible]
Champ	Early, rapid re-growth	6478	425
Climax	Later, taller	6200	487

Orchardgrass

A perennial upright-growing bunchgrass which is moderately shade, heat, and drought tolerant. This grass is very productive in well-managed fertilized stands but is susceptible to winter-killing in areas which are not sheltered and/or are managed poorly.

The recommended varieties are:

Variety	Type	kg. / ha. Forage St. Claude
Frode	Not winter-hardy	3608
Kay	Relatively winter-hardy	5001

LEGUMES

The recommended legumes for Manitoba are shown below:

Crop	Uses	Seeding rate kg/ha (lb/ac) Forage	Seed	Time to harvest Hay	Seed
A. All soil zones except where drainage is poor.					
Alfalfa	H,S,P*	7(6)	2(2)	**	pods brown
Sweet clover	Hay, Seed	11(10)	7(6)	**	pods brown
B. Soils with ample moisture, good drainage.					
Birdsfoot trefoil	Seed, Pasture	2(2)	2(2)		***
Red Clover	Hay, Seed	7(6)	3(3)	**	pods brown
C. Poorly drained areas subject ot temporary flooding.					
Alsike	Hay, Seed	4(4)	2(2)	**	pods brown
Birdsfoot trefoil	Seed, pasture	2(3)	2(2)		***
D. Saline soils.					
Alfalfa	Hay	7(6)		**	
Sweet clover	Hay	11(10)		bud stage	

* H,S,P is Hay, Seed, and Pasture

** early bud stage

*** consult your seed dealer or agronomist as shattering is a problem

A brief description of these legumes and the varieties recommended follows.

Alfalfa

A tall, bushy perennial with a deeply penetrating root system. This plant produces high yields of very palatable forage. Recommended varieties possess adequate winter hardiness and disease and insect resistance. Drought resistance, flood tolerance and salinity tolerance are very good, fair and moderate, respectively.

The recommended varieties are:

		kg. / ha.	
		Forage	Seed
Variety	Type	Glenlea/St. Claude	Arborg
Early Maturing:			
Anchor	Hay	7469 (11)*	557 (7)
Angus	Hay	7202 (12)	565 (4)
Banner	Hay	7015 (12)	485 (4)
Blazer	Hay	7598 (6)	506 (5)
Chimo	Hay	6993 (8)	540 (3)
Hunter	Hay	7010 (8)	534 (3)
Thor	Hay	6924 (12)	655 (4)
Vista	Hay	7480 (16)	523 (5)
Medium Maturing:			
Algonquin	Hay	6899 (13)	631 (4)
Beaver	Hay	6791 (16)	627 (7)
Rambler	Pasture	6492 (16)	516 (7)
Rangelander	Hay and Pasture	6717 (12)	543 (4)
Spredor II	Pasture	6600 (1)	663 (2)
Vernal	Hay	7117 (16)	499 (7)

*The figure in parenthesis indicates the number of years of results.

Alsike

A perennial legume, which produces numerous semi-prostrate stems. It is a moisture loving, flood tolerant, competitive species suited to areas with a high water table. Drought resistance and salinity tolerance are both poor. Produces high yields of very palatable forage in combination with grasses such as timothy and reed canarygrass.

There are no recommended varieties of alsike.

Birdsfoot trefoil

A non-bloating perennial legume which produces many fine semi-prostrate stems. Moderately tolerant of drought and flooding. Relatively poor salinity tolerance. Competitive ability is poor in seedling and established stands. Forage is very palatable; recommended winter-hardy varieties produce 30-50% less forage than recommended alfalfa varieties. It is grown for seed or pasture.

The recommended varieties are:

Variety	Type	kg. / ha. Forage	Seed
Cree	Good seedling vigor	4350	579
Empire	Short, poor seedling vigor	4120	---
Leo	Tall, good vigor	4860	586

Red Clover

A short-lived, medium tall legume suited to areas with a high water table. Drought resistance and salinity tolerance is poor. Red clover is a competitive plant which is susceptible to many diseases which weaken the plant and remove it from a stand within two or three years. This crop produces moderate yields of very palatable forage. Single cut varieties are grown for seed production in the more northerly parts of the province.

There are no recommended varieties in Manitoba.

Sweet Clover

This is a tall upright biennial legume, with an extensive root system. It possesses moderate tolerance to drought and to salinity but is not tolerant to flooding. Recommended varieties are winter-hardy and competitive but susceptible to sweet clover weevils which frequently destroy seedling stands. Sweet clover produces high yields of forage which is fairly palatable in the early growth stages. Some varieties contain high levels of coumarin which in poorly cured hay may lead to feeding and animal health problems.

The recommended varieties are:

Variety	Type	kg. / ha. Forage	Seed
Norgold	yellow blossom, low coumarin	4898	405
Polara	white blossom, low coumarin	2831	305
Yukon	yellow blossom	4722	532

GRASS-LEGUME MIXTURES

Most of our forage areas are seeded to mixtures of grass and legumes. This permits plants to become established where they are most suited. Such mixtures also produce more forage than do pure grass stands and are more easily cured and handled than pure legume forage.

The following mixtures are recommended in Manitoba:

Mixtures	Seeding rate kg/ha (lb/ac) Pastures	Hay	Time to harvest
A. All soils except where drainage is poor.			
Bromegrass &	7(6)	3(3)	Alfalfa in bud
alfalfa	3(3)	7(6)	
Intermediate wheatgrass &	7(6)	3(3)	Alfalfa in bud
alfalfa	3(3)	7(6)	
B. Soils with ample moisture, good drainage.			
Orchardgrass &	7(6)	7(6)	Early heading
timothy	2(2)	2(2)	
Timothy &	2(2)	2(2)	Alfalfa in bud
alfalfa	3(3)	7(6)	
Timothy,	2(2)	2(2)	Alfalfa in bud
orchardgrass,	7(6)	3(3)	
and alfalfa	2(2)	7(6)	
Timothy &	2(2)		
birdsfoot trefoil	2(2)		
C. Poorly drained areas subject to temporary flooding.			
Reed canarygrass,	9(8)		
timothy &	2(2)		
birdsfoot trefoil	2(2)		

Reed canarygrass		9(8)	Early heading
timothy &		2(2)	
Alsike clover		4(4)	
D. Light soils and areas deficient in moisture			
Crested wheatgrass	8(7)	5(5)	Alfalfa in bud
and alfalfa	2(2)	5(5)	
E. Saline soils			
Tall wheatgrass,		5(5)	Early heading
slender wheatgrass		5(5)	
alfalfa and		3(3)	
sweet clover		3(3)	

III. ESTABLISHING A FORAGE STAND

Selection of Seed

Recommendation -- Use certified seed of a recommended variety. These varieties will be suited to your conditions. Certified seed has acceptable germinability and a low percentage of weed seeds.

Seed Treatment

This includes scarification, inoculation and fungicide treatment.

(a) Scarification -- Check the percentage of hard seed of any legume seed lot you use. If the seed was not purchased from a seed house, it may be necessary to scarify or "scratch" it. Most legumes contain hard seeds; some seed lots may contain over 50% hard seed. In these lots, germination will be poor because the seed coat prevents the uptake of water necessary for germination. Most seed houses pass legume seed over an abrasive surface to break the seed coat thus increasing the percentage of seed which can take up water and germinate.

(b) Inoculation -- All legume seed should be inoculated just prior to seeding with the appropriate nitrogen fixing rhyzobium bacterium (inoculum). Commercial, pre-inoculated seed may carry adequate rhyzobia if it has been recently (within a year) inoculated and properly stored (cool, dry conditions). The reasons for inoculating legumes are:

1. Legumes without rhyzobia are soil-depleting crops.
2. Rhyzobia take nitrogen from the air and put it into the plant, lessening its dependence on soil nitrogen.
3. Rhyzobia are not found naturally in all soils and may not even occur in soils where inoculated legumes have previously been grown.

(c) Fungicide treatment -- Use healthy, viable seed. Treat with fungicide only as an extra precaution. Many of the diseases attacking forage seedlings are soil-borne rather than seed borne and seed treatment will be moderately beneficial only. Seed treatment of poor quality seed may increase germination but only infrequently results in better mature stands and higher yields. For good stands use healthy seed. Fungicides may also be harmful to the rhyzobia in inoculum. If fungicide is used, inoculum should be applied at an increased rate immediately prior to seeding.

Seedbed Preparation

Recommendation -- Forages should be seeded into a fine, firm seedbed at a depth of less than 2.5 cm. Stubble and similar residues should be well-chopped and incorporated in the year prior to the seeding operation. Seeds require moisture and air in order to germinate. Forage seeds are small and contain relatively little food reserves so if a seedling is to survive it must begin to make food shortly after germination. A firm seedbed puts the seed in contact with moisture and a fine seedbed discourages rapid moisture loss. Seeding at a shallow depth encourages rapid emergence. While crop residues add organic matter to the soil and may reduce crusting of the soil, a high trash content results in a loose seedbed where uniform seeding is difficult and moisture loss near the surface is high.

Time of Seeding

Recommendation -- The best time to seed forages is early in spring. Pure stands of grasses may be seeded in August or early September if moisture supplies are adequate. Both grasses and legumes may be seeded in the fall immediatley prior to freeze-up. All seedlings require moisture for germination. Most forage crops, excluding such warm season crops as millet or sudan grass, emerge and grow more

rapidly when days are warm and nights are cool. These growing conditions are most often realized in spring. In addition, stands established in the spring have a longer period for leaf, stem and root development. Such stands produce food reserves and are large enough to act as snow traps and thus are better able to survive the winter. This is especially important in legume establishment; relatively young stands of grass are capable of surviving prairie winters. Seed planted just prior to freeze-up should not germinate at time of seeding; the seed has simply been positioned to take advantage of spring moisture and temperatures.

Rate of Seeding

Recommendation -- The recommended seeding rates are supplied in the previous tables. These rates are intended as guidelines only. Seeding rates may be decreased if the area to be seeded is well-worked, fine, firm, fertile and with a good supply of moisture. Seeding rates may have to be increased if seed bed preparation is poor, the soil unfertile, stoney, saline, or otherwise undesirable. The number of plants which can survive and be productive per square meter of land area is relatively small (roughly 3-9, depending on the individual plant size, i.e. 80,000-240,000 plants per hectare). Each kilogram of forage seed contains in excess of 250,00 seeds and, while not all of these will survive and produce a mature plant, it is obvious that seeding rates do not have to be very high in order to obtain reasonable stands.

Uses of Companion Crops

Recommendation -- Companion crops may be used where erosion or weeds are problems or where they provide an economical return in the year of forage establishments. Companion crops should not be used where moisture or fertility is limited. Oats, barley, wheat and flax may be used if seeding rates are reduced 1/3 to 1/2.

The use of a companion crop in forage establishment increases significantly the number of seedlings per unit area. There will be competition between and within crops. The large vigorous cereal seedling possesses an advantage over the smaller forage seedling in the competition for moisture, light and nutrients. Companion crops

usually reduce forage yields in the year of establishment and in the first harvest year. Early removal of the companion crop will enhance development of the forage seedling. Close clipping of the companion crop should be avoided as it also removes the limited leaf area on the forage seedling.

Use of fertilizer in seedling stands

For specific recommendations have your soil tested. Take samples at depths of 0 to 15 cm (0 to 6 in.) and 15 to 60 cm (6 to 24 in.) prior to establishment or on established stands if the possibility of a sulphur deficiency has not been eliminated. Sampling to 15 cm (6 in.) is useful only on established stands where sulphur levels are known to be adequate.

For new stands, phosphorous fertilizer can be applied most effectively by banding the material 2.5 cm (1 in.) to the side and 2.5 cm (1 in.) below the seed. If phosphorous cannot be banded, incorporate it and all other fertilizer materials into the soil before seeding.

	RATE OF NUTRIENT TO ADD (kg/ha)			
Grasses	N	P205	K20	S
Fallow	0-20	30-50	(1)	(2)
Stubble	45-70	30-50	(1)	(2)
Legume and grass-legume	0	60-85	(1)	(2)

1. Sands, sandy loam and organic soils are frequently low in available potassium. On these soils apply 50-100 kg/ha to grasses, and 65-170 kg/ha of potash (K20) at the time of establishment.
2. Low sulphur levels can occur in any Manitoba soil. When required, apply 15 kg/ha of sulphate sulphur to grasses and 30 kg/ha of sulphate sulphur to legumes, especially on sandy soils and grey

The above guidlines suggest that forage crops make heavy demands on nutrients. Type of fertilizer, rate and method of application are important in encouraging symbiosis and in maximizing early plant development.

Weed control in seedling stands

Recommendation -- Cultural practices are a preferred preventative practice. Good practices include tillage to destroy weed seedling, the use of viable, weed-free seed and the use and placement of fertilizers to encourage seedling growth. Mid-summer (August) seeding of grasses may avoid weed competition. Pre-emergent or post-emergent herbicides may be needed to assure good weed control in some situations. Because many forage stands are mixtures of grasses and legumes, it is difficult to use herbicides since they may select against one or more of the components of a mixture. Please refer to the M.D.A. "Guide to Chemical Weed Control."

IV. MANAGEMENT OF ESTABLISHED STANDS

If a companion crop is seeded with the forages being established it should be harvested as soon as possible. The companion crop may be harvested as a hay (green feed) crop; this results in early, rapid and complete removal of the competing crop. Stands are sometimes grazed but in order to remove the companion crop quickly the stocking rate must be relatively high; in addition grazing of such stands should be carried out during periods of dry weather in order to minimize trampling and pulling damage to the young, establishing seedling. If the companion crop is grown for grain, it should be removed as early as possible and the straw remaining should either be removed or some effort made to spread it over as much of the field as possible.

In subsequent years harvesting practices will vary according tho the way a crop is being utilized. In stands where a legume makes up the major portion of the stand it is advisable not yo clip or graze the stand severely during late August through September because this prevents storage of reserves needed by these plants to survive the winter and start growth next spring.

Established stands should be fertilized annually. Annual broadcast applications of fertilizer on established crops may be in late fall or early spring. Do not apply fertilizer to frozen soils subject to water runoff. Established grass stands should be

fertilized with granular fertlizers. Nitrogen solutions sprayed onto established grass stands have been found unsatisfactory and this application technique is not recommended.

A general guideline for fertilizer application is as follows:

	RATE OF NUTRIENT TO ADD (kg/ha)			
	N	P2O5	K2O	S
Grass	100-120	20-35	(1)	(2)
Legumes	0	45-60	(1)	(2)
Grass-legumes	0	45-60	(1)	(2)

1. Sands, sandy loam and organic soils are frequently low in available potassium. On these soils apply 35-70 kg/ha of K2O on established grass stands, and 45-110 kg/ha K2O on established legume stands.

2. Low sulpher levels can occur in any Manitoba soil. When required, apply 15 kg/ha sulphate sulphur to established grass stands and 30 kg/ha to established legume stands being grown on well-drained sandy soils and grey luvisol (grey wooded) soils.

Timing of fertilizer application

A. For seed production

Meadow fescue	October or April
Timothy	October or April
Russian wild ryegrass	Right after harvest
Wheatgrass	Right after harvest
Bromegrass	Right after harvest

B. Forage production

The relative efficiency of broadcasting granular nitrogen fertilizers to established grass at different times of the year is as follows:

1. Spring application	April to mid-May	100%
2. Fall application	October	78 %

For specific guidelines have your soil tested and apply fertilizer according to soil test recommendations.

Weeds should not be a problem in well-managed good forage stands. However, weeds may be present as a result of poor establishment practices (weedy land, poor seed, etc.) or as a

consequence of overgrazing and winterkilling which may reduce the number of forage plants present. Chemical weed control is difficult in grass-legume stands because of the tendancy of most herbicides to select against one of the components in the mixture. For general guidelines for controlling weeds in established stands of grasses and legumes refer to the M.D.A. "Guide to Chemical Weed Control."

V. UTILIZATION OF FORAGE STANDS

The objectives in grassland management are to remove from a forage area annually and over a period of years the maximum amount of the most efficient feed while at the same time leaving the plants healthy and productive. It is important, therefore, to remember the following general guidelines in choosing and utilizing forage species.

1. The more frequent and severe the defoliation, the greater the reduction in leaf and root system and the less the total yield and plant survival.
   - -some wheatgrasses, fescues, and ryegrasses produce early spring growth; their total production and persistance will be decreased if they are grazed not only in spring but continuously throughout the year.
2. Plants can withstand defoliation in proportion to their ability to develop new growth in spite of clipping grazing.
   - -plants such as bromegrass and alfalfa are erect and all their foliage is exposed to the grazing animal or mower. They will persist in stands only if some care is taken to avoid frequent and complete removal of stems and leaves.
   - -plants, such as brome, with erect growth habits are less efficient than prostrate or clump plants (Russian wild ryegrass, bluegrass, fescue) in the production of side shoots and tillers. Bromegrass is, therefore, a good hay crop while Russian wild ryegrass and similar grasses are excellent pasture crops.

VI. PASTURE MANAGEMENT

In pasture management, it is important to choose the most approprate species and to use good weed control and fertlity programs. The most important factor, however, is good grazing management.

All of our recommended grass and legume species can be used in patures. Tall, erect species such as bromegrass and alfalfa will require relatively long rest periods between successive grazings. Prostrate and bunch type grasses and lequemes such as blue-grass, Russian wild ryegrass, fescues and birdsfoot trefoil can tolerate persistant grazing because they escape severe defoliation by having the bulk of their leaf area at or near the soil surface where it cannot be grazed. The crown and axillary buds which give rise to new tillers are also located at or near ground level.

Premature grazing is undesirable. Pastures should not be grazed until there is 10 - 20 cm of growth. Stocking rate should be determined according to type of animal and the amount of pasture and supplementation available. e.g. Dairy cows will, in general, require more and better quality of feed than beef cows where maintenance is the major consideration. On productive pastures a high stocking rate is preferred. Light grazing may result in the production of higher yields of dry matter but this dry matter is offered to the livestock in a less palatable, less digestible condition. Furthermore, livestock will tend to graze selectively either the young growth or certain plants within the mixture. Unpalatable or undesirable plants, including weeds, will not be grazed and will tend to dominate and crowd out the more desirable plants. A heavier stocking rate will prevent forage from becoming mature. Palatability and digestibility will be increased and competition between plant type will be decreased since there is less tendancy for selective grazing. Extremely heavy grazing (overgrazing) should be avoided since it tends to weaken plants, decrease dry matter production, decrease soil fertility and increase weed infestation.

On productive permanent and semi-permanent pasture, the detrimental effects of heavy stocking rates may be offset by

practicing a pasture management system which allows the cattle access to a limited area at any time. This scheme of rotational grazing divides a pasture into a number of paddocks or areas through the use of permanent or electric fencing. Generally, paddock sizes are adjusted to herd size, e.g. 10-12 animals per hectare for a period of 7-10 days. This system allows plants recovery periods between grazing while at the same time it increases production of food quality forage and decreases selective or unequal grazing. Similar results may be achieved by confining the animals and clipping and hauling the forage to them (mechanical grazing). This practice is, however, expensive of time, labor and machinery (tractors, wagons, forage harvesters) and is usually recommended only where pastures are productive and herd sizes large.

VIII. HAY MAKING

Good quality hay is leafy, palatable, of a good green color and free from toxic materials and foreign material. The first steps in the production of good quality hay is the choice of leafy, tall, erect species and the establishment of these species on clean, fertile land. The final quality of hay produced is determined by harvesting, handling and storage and these three factors alone can influence feed value by 25% or more.

The time of cutting is related to stage of growth. Most legumes should be harvested at about the 1/10 bloom stage and most grasses should be harvested soon after heading. Clipping at a later date may give higher dry matter yields but the quality of the product will be decreased, i.e. the total feed value may be the same or less than that from the earlier harvest.

Hay should be managed to permit rapid curing with a minimum of handling. It is desirable to cut at any one time only as much forage as can be handled in a relatively short period (2-3 days) of time. Persistant exposure to dew and rain results in the loss of water-soluble nutrients which make up an appreciable fraction of the total feed value of the hay. Conditioning, especially in heavy crops, will speed drying by as much as 30% since it allows the stems

to dry almost as rapidly as the leaves the final result is a saving of time and nutrient content since there will be less leaf loss.

Hay should be baled (or otherwise collected and stored) at a moisture content of approximatley 20% (when it feels dry and breaks on twisting). If auxiliary drying equipment is used hay may be picked up at higher moisture levels (35-40%). Regardless of the method, good storage is desirable. Hay should be placed in a hay shelter or covered with some type of rain-proof material such as plastic sheeting or treated canvas tarpaulins. These covers should be tied down securely to avoid wind damage. Plastic sheets may also be secured with bales, loose hay or other weights.

VIII. SILAGE MAKING

Silage is an alternative to hay. It can be made from a variety of crops including weathered, frozen or otherwise damaged crops. The best silage is produced from crops which are undamaged by weather or growing conditions. Forage for silage requires little or no field drying and, as a result, there is relatively little field loss. Some nutrient loss occurs in the ensiling process but this is the price which has to be paid for safe storage. Ensiling losses may be lower than nutrient losses in hay making; if losses are higher the silage making process is probably inadequate at some stage. Losses vary with type of silo, nature of the ensiled material and other management factors.

Silage may be stored in upright or tower silos or in horizontal (trench, bunker, etc.) silos. The latter type is most commonly used because it costs less to build. Ensiling losses may be higher and handling more difficult in these silos.

There are three main methods of making silage.

1. Direct-cut silage--The crop is cut and put directly into the silo. Since the moisture content of the forage should be no more than 65% this may mean harvesting more mature (alfalfa in full flower and grasses fully headed) forage. Ensiling at a higher moisture content increases seepage losses, decreases quality of silage and increases the problem of frozen silage in winter.

2. Wilted silage--The harvested forage is allowed to dry in the windrow for 2-3 hours or until moisture is reduced to approximately 65%. This permits the farmer to harvest less mature forage thus increaseing the quality of silage produced. Seepage losses and

Low moisture silage--The harvested forage is allowed to dry in the windrow until the moisture content drops to approximately 45%. Although the weathering losses are increased, storage losses and losses due to freezing are low.

In all of the silage making operations it is important to:

(a) chop the forage (6-12 mm setting) to facilitate packing;
(b) fill the silos rapidly to minimize surface spoilage;
(c) add a preservative (carbohydrate, acid, etc.) to hasten the silage process;
(d) pack rapidly and completely to exclude air;
(e) cover surface to decrease surface spoilage and prevent rain penetration.

IX. NATIVE FORAGE

Native stands of grasses make up a major portion of the total grazing area in some parts of the province. Native vegetation is less productive of dry matter than seeded farage crops. This is attributed to a combination of "poor" species of grazing plants and the growth of weeds and non-productive plants. Also native grasses do not give an economical response to management alternatives such as the application of fertilizer.

The following tables give some comparisons between the yields of fertilized and no-fertilized native and tame hay crops.

Effect of Fertilizer Application on Native Upland Pasture

kilograms	1st year		2nd year		3rd year		4th year		5th year	
	kg	%	kg	%	kg	%	kg	%	kg	%
0.....	279	100	335	100	350	100	449	100	501	100
N at 67 kg*...	349	129	398	119	344	98	455	101	477	95
P at 57 kg*...	297	106	369	110	357	102	480	107	507	101
mean increase over check	75	21	49	14	0	0	18	4	-3	-1

* Fertilizer applied in first year only.

H. Gross, Brandon Experimental Farm

Effect of Fertilizer Application on Native Meadows

Year	Nutrients applied/hectare	Yield kg/ha
1966	0 - 0 - 0	1532.20
	55 - 28 - 0	2770.60
1966	0 - 0 - 0	778.40
	60 - 31 - 0	2072.00
1967*	0 - 0 - 0	1013.60
	102 - 54 - 0	2013.76

* Results indicate a very definite response to fertilizer but the cost of application frequently exceeds the market value of the dry matter produced.

G. Breakey, M.D.A.

The quality of native forage varies with species, location and time of harvest. In general, production peaks in June and tapers off rapidly throughout the summer. While the quality of the forage is adequate, it is usually inferior to tame forage at a similar growth stage. This inferiority is magnified when differences in total dry matter produced is considered.

A Comparison of the Quantity and Quality of Tame and Native Forages

	Native Forage	Alfalfa-Intermediate Wheatgrass Forage
Fat	3.2%	2.4%
Protein	5.6%	15.0%
E.T.D.N.*	49.0%	57.4%
Dry Matter	93.8%	89.4%

* Estimated total digestible nutrients.

Native pastures have low carrying capacities and large land areas are required to support each animal unit. The grazing season is shorter than that for tame stands and the rate of gain or production per unit area is as a consequence usually much lower.

	Native Pasture	Tame Pasture
Avg. gain of yearlings	171 kg	324 kg
Avg. daily liveweight gains	1.36 kg	2.41 kg
Days on pasture	125	134

Good management requires an accurate estimate of carrying capacity of the pasture. Approximately 350 kgs of air-dried hay is required per animal unit (450 kg cow) per month. Overgrazing during the early spring is a common error in Manitoba. A 50% increase in carrying capacity may be realized if native pasture is not grazed until mid-June. A carryover of approximately 45% of the current year's growth should on the average be left in the field to allow for survival and regrowth. Pasture production is reduced seriously and weeds flourish if the productive species are weakened or destroyed by over-grazing. Herbicides may be used to contol weeds. But, it is often difficult to renew the productive species after over-grazing.

Production from native meadows may be increased by a number of management practices. The most common of these include eradication or controlling undesirable plants, re-seeding programs and the use of fertilizers.

Eradicating or controlling undesirable plants is realized through the use of mechanical, chemical or biological techniques. Mechanical control includes bulldozing, chaining, mowing, digging or burning. Selection of the method depends on the species present, area involved, need for seedbed preparation and similar factors.

Chemical control of undesirable species is probably the most commonly used method today. Chemical defoliation is most effective when the plant's food reserves and ability to produce re-growth are at their lowest point. Eradication of large area of undesirable range by herbicides is seldom possible unless repeated applications are made or when this method is combined with other methods of eradication or control.

Biological control of undesirable species involves increasing grazing pressure so that livestock are forced to consume previously unselected species; the use of different classes of livestock such as sheep or goats instead of cattle and the use of insect predators to control some noxious plants in pasture areas.

All of the control methods are appropriate for specific situations and all are associated with significant (threefold to tenfold) increases in forage dry matter production.

Many meadows may be improved by some measure of renovation and re-seeding. If the area is potentially productive and the land can be tilled it may be advantageous to break the land and establish a seeded pasture using recommended species. If the area cannot be renovated and/or there are problems of salinity, access, etc., it may be advisable to sod-seed or interseed the meadow. The purpose here is to modify rather than replace the existing plant stand. It consists of using a press drill and/or scalping (mechanically or chemically) a furrow to remove competition and seeding adapted, vigorously competitive species in the furrow. The preferred species is alfalfa but a number of grasses (slender and crested wheatgrass, Russian wild ryegrass, timothy, brome, etc.) and legumes (alsike, birdsfoot trefoil) have been used with variable success. Fertilizer is usually applied at the recommended rates at the time of seeding and annually thereafter.

Native Meadow Renovation Project

Forage production in kg/ha

Year	Sod-seeded	Native check	Rotovated and seed
1966	585	484	1994
1967	852	538	3039
1968	4211	672	4909
1969	5533	700	5100

G. Breakey, M.D.A.

Complete renovation and seeding is more rapid and probably more economical and effective on productive, less-erosive sites. Sod-seeding has been especially effective on lighter soils; on heavy clay soils problems of equipment operation and soil crusting have been encountered.

X. A METHOD FOR ESTABLISHING NEW FORAGE STANDS ON SALINE SOILS

A successful method for establishing forages on saline soils in Western Manitoba has been demonstrated by reserachers at the Brandon Experimental Farm. The method recognizes three main problems in establishing forages on saline soil:

1. Seedlings are very sensitive to salt. It is preferable to lower the salt content even if it is only for a centimeter or two below the surface. This can be done by growing a crop which lowers the moisture at the surface. Summer rains then drop and wash salt down, and even if it is only moved a little way this would benefit the seedlings.

*N.B. To keep the salt down, don't cultivate or work the land in any way prior to seeding alfalfa. This only brings the salt back up.

2. Saline soils are often very weedy. Weeds are difficult to control when forages (particularly alfalfa and legumes) are in the seedling stage. Growing grass only for several years permits control of weeds by spraying; then legumes can be established.

3. Saline soils are often low in fertility. In fact much of the problem blamed on excess salt may be inadequate phosphate nutrition.

The following seeding method has been used at Brandon on saline soils. It may also be good for wet soils which are often weedy and low in fertility.

1. In the first year, seed a crop which will tolerate salt best- possibly oats.
2. Seed grass into the oat stubble in the late fall without prior cultivation.
3. Apply 27-14-0 fertilizer at 112 - 168 kg/ha during the first and second year.
4. Do not harvest or graze the first year after seeding grass.
5. Spray the first year after seeding with 2,4-D as required.
6. In the very late fall (at freeze-up) of the third year, seed alfalfa directly into the sod. Alfalfa should not germinate until the next spring.
7. Apply 11-48-0 at 34 - 112 kg/ha each year therafter. Do not overgraze, or cut at the wrong time. Weeds, particularly foxtail barley, will return readily.

X. PLANT DISEASE CONTROL

Disease losses are serious every year in Manitoba. They result in reduced yield, grade or marketability and occur at planting, growing, harvesting or storing. An average of 5% loss occurs annually in cereal crops and special crops. In some years when disease incidence is high, disease loss can be up to 100% in individual fields.

A disease can be defined as any process that interferes with the normal growth of a plant. Diseases can be very destructive resulting in death of the plant such as in severe root rot or may result in only slight damage such as an occasional spot.

Plant diseases can be divided into two broad categories:

A) Non-infectious diseases caused by:
   1. nutrient deficiencies
   2. extremes of temperature, hot or cold
   3. excess or deficiency of water
   4. deficiencies of soil nutrients
   5. mechanical damage

B) Infectious diseases caused by:
   1. microscopic organisms such as fungi, bacteria, viruses and nematodes
   2. less common causes are mycoplasma like organisms (MLO), slime molds, and parasitic plants.

Most micro-organisms are beneficial for natural decay. Only relatively few cause plant diseases. Harmful ones can cause serious disease loss. The principal disease causing organisms in Manitoba are fungi. Bacteria and viruses cause only a few diseases. Nematodes have not been troublesome in Manitoba except on a few crops such as sugarbeets and greenhouse crops.

The only disease of any consequence in Manitoba suspected to be caused by a mycoplasma like organism (MLO) is aster yellows of barley, wheat, canola, buckwheat, flax, lettuce, carrots and celery. Serious yield losses seldom occur in the cereal and special crop hosts but aster yellows can be very destructive to vegetable crops.

Parasitic plants seldom cause diseases in crops but can cause severe damage to forest trees, eg. dwarf mistletoe of Jackpine and spruce. Dodder is a parasitic plant which is occasionally found attacking flax.

Slime moulds are very rarely encountered as a cause of plant disease, eg. slime moulds of strawberries.

DISEASE DEVELOPMENT

Infectious disease results when susceptible plants are invaded by a disease causing organism. The severity of plant disease is directly influenced by weather. The relationship is usually complex involving moisture, temperature, wind and light. Infectious disease organisms such as rust or smut spores are spread by winds. Bacteria are commonly spread by splashing rain. Viruses and MLO are often spread by insects such as aphids and leaf hoppers.

In order for a disease to develop, conditions must be suitable for infection and subsequent development of the disease. Most fungi and bacteria require free water on the plant surface for spore germination and subsequent infection, which can come from dew, rain or fog. Cloudy, foggy weather with moderate temperatures favors many leaf diseases. Root rot develops most readily under extremes of wet or dry soils. In both cases plant growth is under stress and the plant is more vulnerable to attack of the disease causing organisms. Plants under nutrient stress are often more susceptible to disease. Some diseases can be partially controlled by applications of fertilizers, eg. browning root rot of wheat is reduced by an application of phosphate and, take all root rot of wheat by potassium chloride applications.

DISEASE CONTOL

Disease control occurs when the life cycle of the pathogen is halted. This occurs when the environment becomes unfavorable for the organism to grow or the plant host is not available for the pathogen to attack.

Disease control can be categorized into several areas. These are:

A) Avoid the disease organism
   1. Select a planting site or field not contaminated by the disease causing organism.
   2. Use varieties that are resistant to the disease.
   3. Bury infected crop residues after harvest.
   4. Practise crop rotation (see Table 1).
   5. Plant early.
   6. Harvest at proper time and store crop under ideal storage conditions.

B) Exclude the disease organism

Certified seed of a number of crops is inspected for disease and when the amount of disease exceeds tolerance limits the field of seed is not certified. eg. ring rot of potatoes has a 0 tolerance. Quarantine laws prevent disease spread from country to country or province to province.

C) Eradicate the disease causing organism or its vector
   1. Remove diseased plants from fields by roguing, eg. potato fields are rogued for virus infected plants.
   2. Separate diseased plant part, or parts of the disease organism from seeds, eg. ergot can be cleaned out of rye seed by a specific gravity seed cleaner.
   3. Soil fumugation eliminates disease causing fungi, bacteria and menatodes.
   4. Insecticides are used to stop an invasion of vectors (aphids, leaf hoppers) that carry viruses and mycoplasmas

D) Protect the crop plant from disease

Chemical protection through the use of fungicide and bactericides. Fungicides kill disease causing fungi on seeds such as smut or seedling decay or blight. Leaves and stems are sprayed to prevent infection by fungi and bacteria causing diseases such as white mold, early blight, bacterial blight and leaf spot.

There are only a few diseases of special crops where fungicides (other than seed treatment) are recommended.

White mold (Sclerotinia) of field beans can be contolled by an application of benomyl (Benlate), thiophanate methyl (Easout), chlorothalonil (Bravo) or iprodione (Rovral) at flowering time. Similarly, white mold (Sclerotinia) disease of canola can be contolled by an application of benomyl (Benlate) or iprodione (Rovral) at blossom time.

Bacterial blight of beans in seed plots can be controlled by several applications of fixed copper fungicide at 7 - 10 day intervals.

There are many recommendations for fungicide applications on vegetables and potatoes. These recommendations are are all listed in the "Field Crop Recommendations for Manitoba".

E) Disease control through crop rotation

Crop rotation, alternating cereal crops with broad leaf special crops will reduce incidence of root rot. Many special crops are subject to the same diseases such as root rot and sclerotinia white mold and thus cannot be grown in the same rotation or must be spaced at least three years apart. These include canola, mustard, field beans, lentils, peas, soybeans and sunflowers.

Table 1 gives an indication of the number of years that various crops should be spaced apart in a crop rotation for disease control. A crop rotation is also affected by herbicides that have a residual action. A detailed chart on crop rotation, integrating, disease, herbicide, volunteer crop and fertility considerations has been prepared by the Manitoba Agronomist Committee. It is not available for for general distribution but copies are available for examination at the local agricultural offices. The crop rotation chart will also be available for viewing on Telidon.

Vegetable crop disease control recommendations are included in the "Vegetable Crop Production Guide"

available from Manitoba Agriculture publications. A pictoral chart illustrating common diseases of special crops and vegetables is also available from Manitoba Agriculture.

FUNGICIDE APPLICATIONS FOR FIELD CROPS AND POTATOES

(other than seed treatment)

Sclerotinia (stem blight, white mold) - Canola

Use seed from disease free fields. Treat seed to control seed rot, seedling blights and blackleg. To control soil-borne diseases follow a crop rotation of at least four years. Avoid fababeans, field beans, field peas, lentils, mustard, soybeans and sunflowers in the rotation because of Sclerotinia stem rot. If necessary, Sclerotinia stem rot may be controlled by aerial applications of benomyl (Benlate) 1.0 kg/ha or iprodione (Rovral) 1.0 kg/ha at the 20 - 30 percent blossom stage. Argentine types are resistant to staghead. Do not sow canola or rapeseed adjacent to canola or rapeseed stubble, and control volunteer seedlings early in the season.

White Mold (Sclerotinia), Gray Mold (Botrytis) - Field Beans

Avoid fababeans, field peas, lentils, mustard, canola, rapeseed, soybeans and sunflowers in the rotation. Any of the following chemicals may be applied as a protectant treatment: benomyl (Benlate 50WP) at 2.2 kg/ha; chlorothalonil (Bravo 75WP) 3.3 kg/ha or (Bravo 6F) at 2.2 kg/ha; iprodione (Rovral 50WP) at 3 kg/ha. These fungicides should be applied at specific flowering times and for details of the precise timing of application see the label of the particular chemical. Thorough coverage of blossoms is essential. Do not apply any of these chemicals within 14 days of harvest. Avoid dense foliage favorable for disease development by restricting nitrogen. Follow a crop rotation of four years to control Sclerotinia and other soil-borne diseases.

Early Blight - Potatoes

Use of one or more of several fungicides according to directions on the label is recommended. Frequently, these disease control measures are combined with applications of insecticides where the mixture is compatible. Apply one of the following fungicides: maneb (Dithane M-22, Manzate D) at 2.2 kg/ha, mancozeb (Dithane M-45, Manzate 200) at 2.2 kg/ha, metiram (Polyram 80W) at 2.2 kg/ha, Difolatan 4.8F at 8.5 l/ha, Bravo 500 at 1.6 - 2.4 l/ha or fixed copper 49 to 55 percent at 1.1 to 3.3 kg/ha.

TABLE 1: CROPS

DISEASE RELATIONSHIP / DISEASE	ALFALFA	BEAN	BEAN	CANOLA	FLAX	FLAX	FLAX	LENTIL	MUSTARD	OAT	PEA	RAPESEED	RAPESEED	TOBACCO	SUGAR BEET	SUGAR BEET	SUNFLOWER	SUNFLOWER	WHEAT	*
Ascochyta Blight							A		B											4
Alternaria-Grey Leaf Spot										X			X							1
Bacterial Blight						A	B									C				1
Cyst Nematode										X			X				X			3
Ergot		X												X	X				X	1
Fusarium Wilt & Root Rot	X					X	X	X	X	X			X			X		X	X		S
Gibberella Fusarium Head Rot		X		X																1
Helminthosporium Common Root Rot		X																	X	2
Rhizoctonia Root Rot	X		X			X	X	X	X	X		X	X			X	X	X	X	S
Sclerotinia	**					X	X		X	X		X	X			X		X	**	4
Septoria (Cereals)		X																	X	1
Verticillium Wilt	X											X						X	X	4
White Rust Staghead									A				B							3

Diseases with different letters have same name on various crops but are caused by different species or biotypes of the pathogen. This implies that there is little risk of this disease spreading between the indicated crops.

* = longevity of pathogen in soil or on trash in years

S = pathogen is a soil organism and can survive indefinitely

** = uncertain

XI. ENTOMOLOGY

INSECT IDENTIFICATION

Over a million and a half insect species are known in the world. Nature keeps insects in balance with the surroundings. But often, man's interference and manipulation of nature causes certain insects to become economic pests. Presently, insecticides are the most effective means of combatting insect infestations.

Due to the number of species of insects, correct identification requires special training. Since some insecticides kill specific insect pests, proper identification of the insect to be controlled is very important. Insect identification services can readily be obtained by sending specimens to:

Entomology Section
Manitoba Department of Agriculture
911 Norquay Building
Winnipeg, Manitoba
R3C 0V8

Carefully pack specimens to ensure they arrive in proper condition.

INSECTICIDE DRIFT

All insecticdes are subject to some drifting, whether applied from the air or by ground equipment. Insecticide drift can cause serious contamination. Users should apply insecticide formulations less prone to drift. Pay particular attention to wind velocity, using insecticedes only when wind very low (less than 12 km/hr.)

SEED TREATING

Usually more seed is treated than sown in any particular year. It is extremely important that seed treated with insecticide be used for seeding only.

It is illegal to mix treated seed with grain to be used for human consumption.

Left-over treated seed cannot be used as feed for livestock of any type. It should be properly tagged and stored for later seeding.

AERIAL SPRAYING

Unless otherwise specified in the recommendations, apply atleast 12 liters of spray solution per hectare (1 gal/ac) to ensure adequate distribution of insecticide. Higher volumes provide better coverage and better control of insect pests.

Carry out aerial spraying only when wind velocity is below 12 km/hr (8 mph).

GROUND SPRAYING

Unless otherwise specified in the recommendations, 90 - 120 liters of water per hectare (8-10 gal/ac) provides adequate insecticide distribution.

Ground spraying should take place when wind velocity is below 12 km/hr (8 mph).

INSECTICIDES AND POLLINATING INSECTS

The following points should be remembered when applying insecticides in the vicinity of pollination insects:

--- All insecticides are toxic to honeybees and other beneficial insects. Farmers, beekeepers, pesticide dealers and pesticide applicators must co-operate closely to minimize insect losses.

--- Only the least toxic insecticides to bees should be used where honeybees or other pollinating insects may be foraging. Notify beekeepers in the area so they have an opportunity to protect their colonies.

--- The application of insecticides during the early morning and late evening hours lessens the possibility of causing injury to honeybees and other pollinating insects.

HOW INSECTICIDES KILL

Insecticides enter an insect's body by contact on its outer shell or by ingestion, and kill by disruption of its nervous system.

Most insecticides, formulated for use as sprays, directly contact the insect on application or have residual contact for a time after application. Most major crop insect pests such as grasshoppers, armyworms, flea beetles and aphids are killed by direct or residual contact from spray applications of insecticides.

Some insecticides are formulated for specialized uses, killing specific insects in specific ways. Common examples are systemic pour-on insecticides for warble grub control in cattle, tree-trunk band applications for aphid control and granular or powder formulations for seed treatments for flea beetle control on canola. Other examples of specialized insecticides are scatter baits for farm fly control, fumugants for stored grain insect control and insecticide impregnated resin strips for indoor fly control. Insecticides, whether in a direct spray or more specialized application have the end result of being absorbed through insects' outer shell or ingested by feeding causing death by disruption of the nerve processes.

COMPATIBILITY OF INSECTICIDES AND OTHER PESTICIDES

In Manitoba, one insecticide will usually combat an insect problem. However, insecticides and fungicides are frequently used together, especially by market gardeners.

In general, most pesticides used in Manitoba are compatible when mixed with another pesticide.

It may be advantageous at certain times to mix an insecticde with a herbicide for insect control on a limited area basis, but it is not recommended as a general practice for the following reasons:

1. Insect and weed problems seldom warrant control at the same time. Waiting to take control of both pests is likely to result in poor control of either or both.

2. Insect problems are specific and often on a limited crop area. Thus, using two pesticides together may result in high costs for unwarranted insecticide.

3. Delays after mixing, because of mechanical or other reasons, can result in loss of effectiveness.

Persons using two or more pesticides together should be advised to take the following precautions:

1. Use products formulated by the same company.

2. Obtain compatibility information from pesticide manufacturer if possible.

3. Apply chemical as soon as possible after mixing.

WATER pH AND INSECTICIDE DEGRADATION

When certain insectideds are added to alkaline water (high pH), they begin to lose their effectiveness. The rate at which degradation proceeds depends on several factors. These include the pH of the water, the amount of insecticide being added and its effect on the pH of the finished spray, water temperature, and the length of time the finished spray is allowed to stand.

The amount of degradation in all insecticides has not been fully explored, but evidence indicates that for many commonly used insecticides, alkalinity in the water used to mix the spray formulation may have very adverse effects on the chemical. One thing is certain: pesticide degradation in alkaline solutions is irreversible and initial effectiveness is lost.

Since there is a considerable amount of high pH water in Manitoba, pesticide users should take note of the insecticide they intend to use and the alkalinity of their source of spray water. When insecticides are to be used that degrade rapidly in high pH water, an alternate insecticide can be considered or the user can consider using another source of spray water with a pH of 7.0 or less.

HOW TO CLEAN A CONTAMINATED SPRAYER

Sprayers contaminated with herbicides can be used for

insecticides without danger to susceptible crops, provided the following cleaning procedures are carried out:

1. Fill and flush out the sprayer three times using clean water.
2. Fill the tank with a mixture of water and ammonia (1 liter ammonia for every 50 liters of water) and let stand for 2 or 3 days.
3. Run it through the machine and wash with soapy water and rinse.

SAFETY IN HANDLING AND APPLYING PESTICIDES

Poisoning -- The two types of poisoning are acute and chronic. Acute poisoning occurs from a single dose of pesticide. Chronic poisoning results from several small exposures over a period of time. Chronic poisoning may become acute if exposure is allowed to continue. It is more dangerous as symptoms can be confused with a cold or other common ailment. If symptoms such as headache, nausea or dizziness occur after exposure to an insecticide, see a doctor immediately, taking a container label with you. Some pesticides normally low in toxicity become much more toxic when used in combination with other pesticides.

Safety Rules -- Insecticides may enter the body through the skin, the mouth and by breathing the vapors. These three pathways are to be considered when handling pesticides. The following precautions should be observed at all times but particular care must be taken when handling the concentrated pesticide during mixing operations.

1. Read the label on the container. This may save your life and prevent accidents. It will name the product and its most effective use. It will also explain how to handle the material and what should be done in the case of an accident.
2. When mixing spray solutions wear PVC hat, gloves and apron as well as chemical goggles, coveralls and an approved dual cartridge agricultural respirator with pesticide cartridge.
3. When mixing seed treatments with seed, always wear goggles, respirator, gloves and arm protection such as a jacket.
4. Never mix spray solutions or treat seed inside a building. Do it outside so that the vapors can blow away.

5. Wear clean clothes each day when using pesticides.

6. Shower each day after using pesticides.

7. If insecticides are spilled on the skin, wash immediately and thoroughly with soap and water.

8. Change contaminated clothes as soon as possible and wash before re-use.

9. While spraying or dusting, prolonged exposure should be avoided, sprays and dusts should not be inhaled, smoking (especially handrolled cigarettes) should be avoided and all exposed parts of the body should be washed immediately.

10. If you are taking prescribed drugs at the same time you are using pesticides, notify your doctor, since exposure to pesticides may alter the effectiveness of a drug.

11. Excercise care and caution when using pesticides, you may save a life or prevent serious illness.

12. If symptoms such as nausea, headache, blurred vision, numbness in fingers occur when using pesticides, see a doctor immediately. Take the pesticide container label with you; it will aid the doctor in his treatment.

13. Take care not to contaminate feed or water for livestock. The rates of application contained on the labels should be followed, and cautions with regard to the use of treated crops strictly observed.

CONTAMINATION OF WATER SOURCES

Use extreme care to avoid accidental spilling of any pesticide into wells, dugouts or other water sources used for human and livestock consumption. Observe the following precautions:

1. If possible, do not fill sprayers directly from wells or dugouts. The use of portable water storage tanks will allow water to warm to air temperature for better mixing and eliminates the possibility of contamination of water supplies.

2. If a sprayer must be filled directly from a well or dugout, the sprayer intake hose should be removed from the water source

before the sprayer pump is stopped. This will prevent backsiphoning of chemical from the sprayer to the water source.

RESPIRATORS AND THEIR CARE

Recommended respirators are the dual cartridge agriculture type that have NIOSH (National Institute of Occupational Safety and Health) approval. The proper cartridge to use will vary depending on the make. When purchasing a respirator ensure that the proper cartridge is obtained by specifying that it is to used with pesticides.

To be completely reliable, respirators must be properly looked after. The following procedures are recommended:

1. Filters should be changed twice a day or more often if breathing becomes difficult.

2. Cartridges should be changed after eight hours of use or oftener if any pesticide is detected.

3. Filters and cartridges should be removed and the face piece should be washed with soap and water after use. Rinse thoroughly and let dry in a well ventilated area.

4. When not in use respirators, filters and cartridges should be placed inside an airtight plastic bag and stored in a clean, dry place.

STORAGE AND CONTAINER DISPOSAL

Store insecticides in a special area which is not normally used by anyone. It should be a warm location to prevent freezing of the insecticide. Labelling and locking of the area is advisable.

Store pesticides in their original containers with label intact. Avoid causing dents or scratches which will weaken the container possible causing leaks. Dispose of leaking containers.

Paper and cardboard cartons may be burned on a hot fire composed of wood soaked in diesel fuel. The temperature generated by an ordinary fire is not sufficient to ensure decomposition. Remember that the smoke from pesticide fires may be toxic. Do not allow the smoke to drift over people, livestock or buildings.

Glass and metal containers must be decontaminated by rinsing thoroughly two or three times with a solution of equal parts chlorine bleach and water. The containers should then be broken or punctured and taken to the municipal dump for burial.

The best known method of disposing of surplus spray mixture is to spray it out in a specific area set aside for this purpose.

Contact the Manitoba Department of Agriculture for any further disposal instructions.

CLEANING UP SPILLS

When cleaning up spills, coveralls, rubber gloves and boots and a respirator should be worn. If chemical is spilled on clothing, or comes in contact with skin, immediately remove clothing and wash skin with soap and water. The clothing should be washed before being worn again.

Liquid Spills

1. Spread hydrated lime over spill in sufficient quantity to soak up liquid.
2. Allow it to sit until all liquid is soaked up.
3. Sweep up and place in a heavy plastic garbage bag.
4. Soak entire area with laundry bleach and spread more lime over the area.
5. Allow one or two hours for decomposition.
6. Sweep up and place in garbage bag.
7. Remove sweepings to dump for burial.

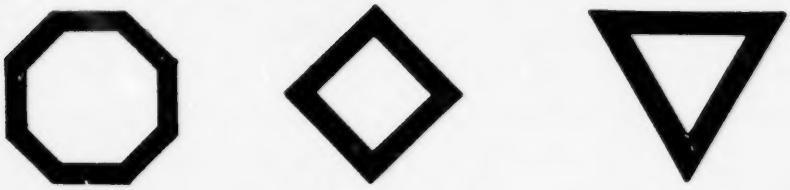
Dry Powder

The procedure is the same as for liquid, except that the powder will have to be wetted before starting clean up.

CLASSIFICATION OF PESTICIDES

Pesticides are classified according to the use hazard and risk involved. The categories and symbols of hazard are shown on the next page.

Degree of Risk Symbols



Danger *Warning* *Caution*

Category of Hazard Symbols

Poison *Corrosive* *Flammable* *Explosive*

MOVEMENT OF NATURAL AIR THROUGH GRAIN

Natural air is moved through grain to prevent grain spoilage and to reduce the energy requirements for drying grain. High grain moisture contents and high temperatures encourage mold growths and insect activity. Drying and cooling grain are therefore the chief methods used to keep grain in good condition and prevent spoilage.

There are a number of methods used to dry and cool grain. Each involves the movement of natural air through the grain. These are: aeration, natural air drying, combination drying, dryeration and in-storage cooling.

AERATION

Aeration is the use of low air flow rates to cool grain and eliminate temperature and moisture differences in the storage bin. Aeration may be used with normally field dried and harvested grain or on grain that is harvested damp, then dried and cooled in a heated air dryer. In both cases, temperature variations may occur as it is put into storage. Variations may also be caused by changes in the outside air temperature after the grain is stored.

Temperature differences can cause moisture migration from warmer to colder areas of the bin. Figure 1 shows moisture migration when temperature differences are created by lower ambient temperatures.

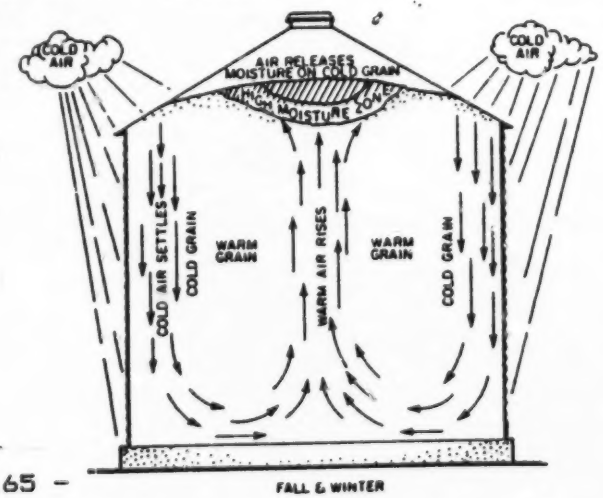


Figure 1.

Warm air rising in the centre of the bin cools when it reaches the cold grain near the surface. Moisture condensation results in an increase in moisture content near the surface and may lead to rapid spoilage. Crusting on the surface of stored grain is a common symptom of moisture migration. In summer, it is possible to get moisture migration in the opposite direction if the outside temperature is warmer than the grain, as shown in Figure 2.

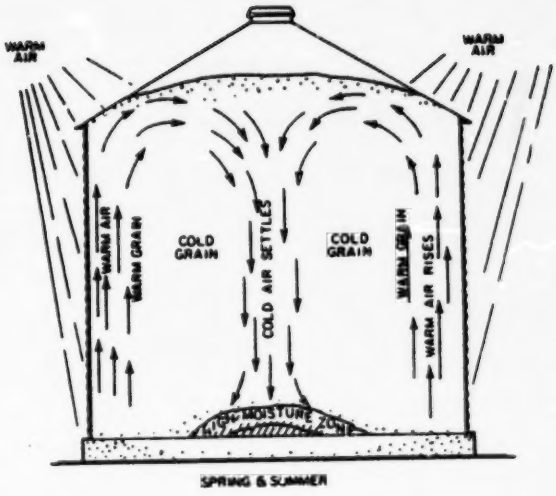


Figure 2.

Larger storage bins and greater outside temperature variations cause a more severe migration of moisture. In western Canada, wide temperature extremes dictate a strong need for aeration systems, particularly in large storage bins (100 cubic meters or larger)

The purpose of an aeration system is to maintain the lowest practical temperature and the least temperature variation within the stored grain. Sometimes these goals are at odds with each other, so a compromise is necessary.

Aeration is NOT a grain drying system and should not be considered as such. Under ideal weather conditions some drying occurs during aeration but the low air flows used are not sufficient for reliable safe storage of grain that is more than 1% above "dry", unless grain temperatures are near or below 0 degrees C. The air flow rates for aeration are normally 1-2 litre of air per second per

cubic meter of grain. Natural air drying rates are usually about 10 times as high.

The amount of air required to change the temperature of the grain will produce very little change in moisture content. If an aeration system is operated for an excessively long time, a significant change in moisture could occur.

At an air flow rate of 1 L/s per cubic meter about 150-200 hours of fan operation are needed to change the temperature throughout the bin. At an air flow rate of 2 L/s per cubic meter it takes only one half as long. It is essential that the fan should be operated long enough to equalize the temperature in the entire bin. The operator must gain experience in changing the temperature in the bin by monitoring the temperatures during periods of fan operation. Non-uniformity in air flow and uncertainty of air flow rates make this necessary. Inadequate fan time is the major source of problems when aerating stored grain. Shutting the fan off too soon may increase temperature variations within the bin, rather than reduce them.

Although stored grain can and is being aerated with air flow rates as low as 0.3 - 0.5 L/s per cubic meter in commercial storages, a minimum of 1 L/s per cubic meter is recommended for on-farm storage. Higher air flows allow the job to be completed faster so that less attention is required. The use of higher air flow aeration (2 to 6 L/s per cubic meter) helps manage stored grain, particularly grains at higher moisture contents (15 to 17%) for feeding and/or blending. Remember, increasing the moisture content of stored grain is accompanied by an increase in storage risk. Well designed

aeration systems and good management allow the producer to gain the advantage of storing grain at higher moisture levels.

Fan Operation

Fall--During the fall, grain must be cooled as quickly as possible. Cooling can be accomplished whenever the exhaust air temperature from the grain is at least 5 degrees C above the maximum daily outside temperature. Run the fan day and night as long as this condition exists, regardless of relative humidity. A day or two of fan operation during rainy weather or other high relative humidity periods does no harm if the fan operates for a day or two of fair weather afterwards. Avoid extensive fan operation during rain or wet weather after the grain has cooled to within 5 degrees C of the average outside air temperature.

Start aerating as soon as the grain is delivered to the bin. Grain cooled in a heated air dryer or grain harvested on warm, sunny days will always be cooled by immediate fan operation. Check cooling progress and run the fan enough to cool the grain to within 5 degrees C of the average outside temperature. Extensive fan operation beyond this should be avoided. Grain temperature may be reduced to the desired level in several steps if necessary.

Cool the entire volume of grain to 0 to minus 5 degrees C for the winter holding period. The top center of the bin cools last with upward air flow while the bottom center is the last to cool with downward air flow.

Winter--When the fans are off during the winter holding period, cover them with metal, canvas, or plywood to prevent the grain near the ducts from being cooled excessively in severe winter weather.

Rodents must also be prevented from entering the ducts. Large temperature differences near the ducts cause condensation in the cold grain. Failing to cover the fan during extended off periods may cause spoilage of grain near the aeration ducts or perforated floor.

During the winter holding period, check the grain weekly. Run the fan periodically for a day or two when the outside temperature is near that of the grain.

Spring--Many operators do not warm stored grain in the spring. If the grain is being moved out by July and has not been cooled below 0 degrees C, it does not need to be warmed. If the grain is being held longer or if it is below 0, warming to 10 degrees C is recommended. This is done in several stages beginning in April. Run the fans in fair weather (night and day) when the average 24 hour temperature is 5 degrees C warmer than the grain and the average relative humidity is below 70%. Operate the fan continuously until the minimum daily temperature is about the same as the bin exhaust temperature.

When the exhaust temperature increases to the new level, wait until the weather warms another 5 degrees C. Then, bring the temperature up another stage. Be sure to warm the entire bin during each stage. If the fan is shut off before the entire bin has warmed, some condensation may appear between the cooler and warmer parts of the bin. This will cause spoilage if the grain is left for more than a few days. Condensation is more severe with larger temperature differences.

Summer--make sure all the grain is warmed to 10 degrees C by mid-June. Cover the fan when it is off during the holding period. If the grain is around 10 degrees C and the duct or plenum chamber is open, condensation may occur in the cooler grain during warm. high humidity periods in summer. This may cause spoilage next to the ducts.

Periodically check the grain and run the fan during cool, fair weather when the outside temperature is close to the grain temperature.

Direction of Air Movement

Aeration can be accomplished by moving the air up or down through the grain. The air delivery system will move about the same amount of air either way. There are both advantages and disadvantages to each direction.

The main advantage of moving air down and exhausting it at the bottom is to minimize roof condensation when aerating warm grain in cold weather. If air is moved upward, the warm air contacting the cold bin roof may cause condensation. Condensation can be reduced by aerating warm grain before the weather gets too cold. Operate the fans in several steps to change the grain temperature more gradually. This is the best way to operate the fans regardless of air movement direction.

The uncertainty of knowing when aeration is complete is the main disadvantage of moving the air down through the bin, since the grain at the bottom is the hardest to check. A thermometer in the exhaust air, preferably on the suction side of the fan helps check aeration progress. However, it only reads the average exhaust temperature and

may not reflect the higher temperature of the air leaving the bottom center. The operator must check for the completion of aeration by probing with a thermometer or by checking the temperature of some grain unloaded through the center hopper.

When moving air upward, aeration progress can be easily determined by checking the grain temperature at the top center. Also, with an upward air flow, the fan can be started immediately and air leaving the duct will help keep the perforations clean as filling starts. Since the air and grain at the top of the bin gets very warm in summer, it is best to move the air upward and out of the bin in summer rather than drawing the hot air down through the rest of the grain.

Duct Systems for Aeration

Many duct and perforated floor arrangements are available for use with aeration systems. For cylindrical grain bins some of the most common include a single perforated duct across the bin floor, a cross duct, a V-shaped duct, and a rectangular perforated area in the center of the bin (see figure 3). These and others are satisfactory if there is a sufficient perforated area and they are centrally located in or on the bin floor. A minimum of 15% of the bin floor area should be perforated for aeration systems in bins up to 6 m high.

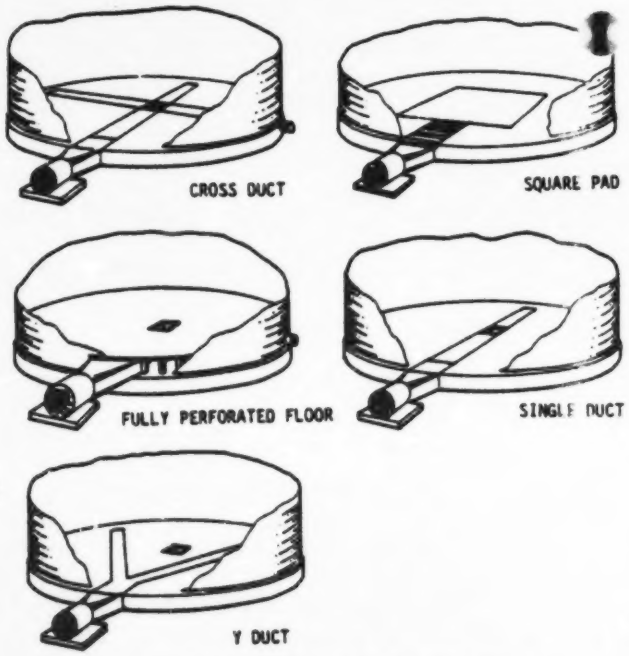


Figure 3. Aeration Duct and Floor Arrangements for Cylindrical Bins.

NATURAL AIR DRYING

Natural air drying uses the drying potential from grain. Air is forced into the bin from the bottom. Moisture is evaporated and carried through opening in the top of the bin (figure 4). The grain above the drying zone remains at or near it inital moisture content. Grain located below the drying zone has a moisture content which is in equilibrium with outside air conditions. These equilibrium conditions are given in Table 1.

TABLE 1

Equilibrium Grain Moisture Contents

Relative Humidity of Air	Equilibrium Cereal Grain Moisture Content at 25°C	Equilibrium Cereal Grain Moisture Content at 10°C	Equilibrium Oilseed Moisture Content at 25°C	Equilibrium Oilseed Moisture Content at 10°C
58%	12%	13%	7.5%	8.5%
65	13	14	8.4	9.4
71	14	15	9.3	10.3
76	15	16	10.2	11.2
80	16	17	11.2	12.2
83	17	18	12.2	13.2
85	18	19	13.2	14.2

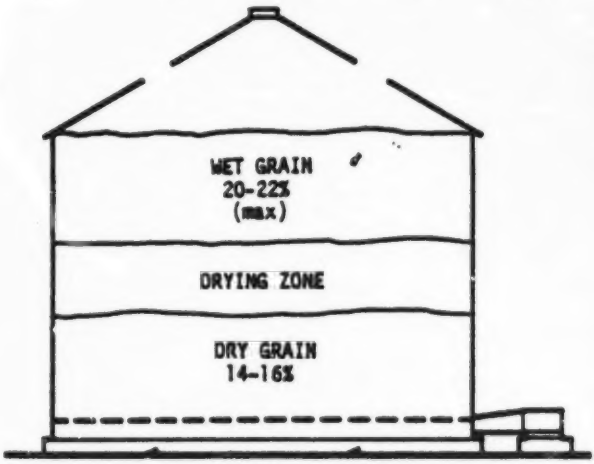


Figure 4 In-Storage Drying.

Natural air drying is a race to get the grain dried before it spoils. The key is to move the drying zone through the top of the bin within the allowable storage time. At higher moisture contents and temperatures, the allowable time for drying is reduced. Wetter grain requires higher air flow rates to accomplish drying within the time allowed. As the termperature increases, the allowable drying time decreases faster than the drying capacity of the air increases, requiring higher air flow rates to complete drying within the time available. Generally, the miminum air flow rate is doubled for each 2% increase in initial grain moisture content, and reduced by 1/2 for each month's delay in harvest.

Grain which is located at the top of the bin is most critical since it is the last to dry. The more air that is delivered, the quicker the drying zone moves through the grain and the more reliable the drying system. Operate the fan continuously until the drying zone moves through the top of the grain. The bottom layer of grain overdries in good weather and re-wets in poor weather. However, as re-wetting occurs at the bottom, the drying zone continues to move upward.

Once the drying zone has moved through the grain, continued operation under typical weather conditions in November and early December causes grain re-wetting at the bottom of the bin. Little or no useful drying takes place at the top of the bin. At this time, grain can be cooled to 0 to -5 degrees C and the fan shut off. Cereal grains with 16 to 18% moisture store well over winter at these low temperatures. Often, additional drying is not necessary. Grain being fed to livestock during the winter can be used at these moisture levels. If the grain is being marketed in the winter and the moisture content must be below 14%, natural air drying may be unsuitable in some years.

If the grain is held past late spring or into the summer either for marketing or for feeding, additional drying may be necessary. Start spring drying in early or mid-April and move another drying zone through the grain. Since there is less total moisture to remove, the drying zone passses through the grain more qwuickly than in the fall. As drying progresses in the spring, temperatures become warmer and humidities lower causing grain located below the drying zone to continue drying. A series of drying zones passes through the bin as drying conditions improve.

Grain at the bottom may be down to 12 to 14% moisture by mid-May because of improved drying conditions. This is a problem with any in-storage drying system since it is often necessary to over-dry the grain in the bottom to complete drying to the desired level at the top.

Management of Natural Air Drying Systems

Fine material and broken grain increases air flow resistance, reducing total air flow. Screening this material out is important for successful natural air drying. Screenings may be fed or put into a silo with other material (remember the fines are wet and will spoil without drying). Since the fines tend to accumulate in the center of the bin, unloading some grain from the center when the bin is full is beneficial.

Keep the grain level to promote uniform air flow. Grain spreading devices help to distribute the grain, and additional hand levelling improves air flow uniformity. Always hand level the grain when you have finished adding grain to the bin. Resistance to air flow is greater in the bin's center than at the outer edges due to increased amounts of fine material in the center. "Dishing-out" the center of the bin is usually beneficial in correcting this. Where possible, draw some grain from the center unloading hopper of the bin. This reduces the amount of grain to be moved while levelling and some of the fine material at the bin's center is removed.

Start the fan as soon as the grain covers the drying floor. Operate the fan continuously until the drying front has moved through the top of the bin. Do not shut the fan off during periods of rainy weather and high humidity in the fall, since fan operation continues

to move the drying front through the grain and the air movement controls grain heating. In late fall or early winter, shut the fan off when the grain temperature throughout the bin drops to -5 degrees C. After turning the fan off, cover it to avoid natural air currents through bin. This also prevents rodents from entering.

During the winter check the top 50 to 100 cm of the bin periodically for moisture build-up, (particularly near the center) or an increase in grain temperature. Run the fan for six to eight hours every two to three weeks if the ambient temperature is near -5 degrees C. This is particularly important following periods when the air temperature goes above 0 degrees C.

In spring, if additional drying is necessary, start the fan and run it continuously when the average daily temperature exceeds 0 degrees C. If the grain is already dry, warm it according to normal aeration procedures. Check the grain temperature at the top of the bin to determine when the warm-up has been completed.

If the grain appears to be heating or going out of condition, move enough grain to stabilize the situation. The grain may be run through a heated air dryer to quickly reduce moisture content to a safe level.

COMBINATION DRYING

Combination drying is a system in which heated air drying is followed by in-storage cooling and natural air drying (figure 5). The heated air phase can be a continuous flow or automatic batch dryer, or a bin dryer using elevated air temperatures (continuous flow; unstirred, stirred or recirculating batch). The heated air dryer reduces the grain moisture content to a level where drying can be

safely completed with in-storage, natural air methods. In-storage drying is accomplished by moving unheated (natural) air through the grain mass. Four to eight weeks or longer may be required to complete the process. Drying may be halted in the late fall and completed the following spring.

Potential advantages of the combination drying approach (as compared to doing all the drying and cooling in a heated air dryer) include:

--reduced energy requirements

--increased drying capacity

--improved grain quality

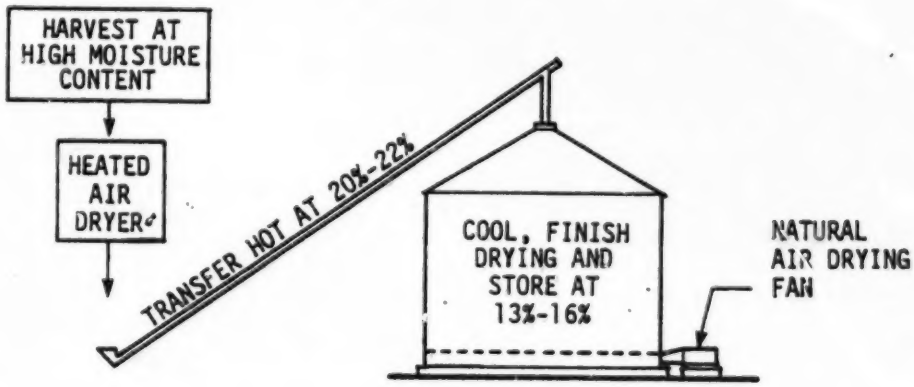

HARVEST AT HIGH MOISTURE CONTENT
HEATED AIR DRYER
TRANSFER HOT AT 20%-22%
COOL, FINISH DRYING AND STORE AT 13%-16%
NATURAL AIR DRYING FAN

Figure 5 Combination Drying.

Propane or natural gas requirements for heated air drying are reduced since less moisture is removed in the heated air phase compared to conventional heated air drying with in-dryer cooling. Total savings depend on the moisture content level at which the grain is discharged from the heated air dryer. Electical energy

requirements are increased due to the fan energy for natural air drying, but overall, energy requirements are reduced substantially as compared to using the heated air dryer for the entire job.

Drying capacity of the heated air dryer is significantly increased since less moisture is removed in the dryer. Cooling is done in the storage bin rather than in the dryer. If the heated air dryer is a batch type, the cooling cycle may be eliminated. In a continuous-flow type, the cooling section of the dryer can be equipped with a propane burner to provide more drying capacity. Capacity increases of 200 to 300% for heated air dryers are possible.

Management of the System

Do not exceed suggested moisture content levels for discharge from the heated air dryer to the bin for cooling and drying. During the first year, reduce the moisture content to 20% or less in the heated air dryer until you gain experience with the system including measuring the moisture content of the warm, moist grain. Since the moisture content of warm grain is difficult to measure accurately, grain samples for controlling the dryer should be taken from the cooled grain in the bin for best results. With the air flows used in natural air drying, grain is normally cooled one or two hours after it reaches the bin.

Start in-storage drying fans as soon as hot grain is placed in the bin to avoid undesirable condensation build-up on the walls of the bin. During in-bin cooling, the hot moist air discharged forms condensation on the bin's roof and eaves. Condensation is not a problem unless water collects and runs along roof supports and is deposited in one place.

The downspout of the bin may be a potential source for problems since moist air rising in it will cool and water will condense and return into the bin. One solution is to close the entrance to the downspout at the bin preventing air from travelling up the spout. Spring loaded covers that automatically close when grain is not flowing are avilable.

DRYERATION

The typical heated air drying process uses heated air followed by rapid coolin of the grain in a dryer before transferring to storage. Dryeration (figure 6) modifies this high-speed drying process by transferring the hot grain tc a cooling bin. In-dryer cooling is eliminated. After cooling, the grain is transferred to storage. Dryeration provides three advantages over high-speed drying with in-dryer cooling:

increased dryer capacity

reduced fuel consumption

better grain quality

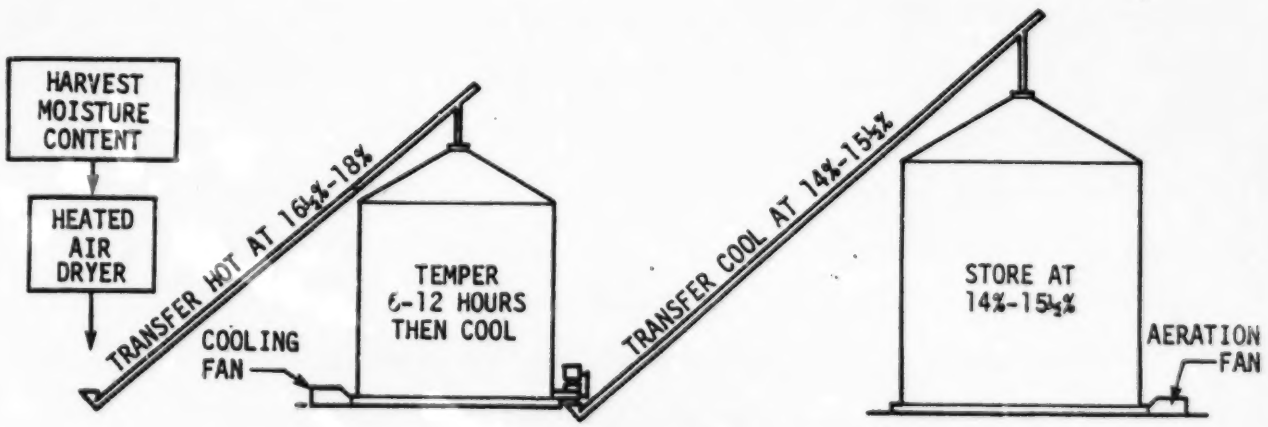


Figure 6 Dryeration.

Grain is delivered hot from a heated air dryer to a dryeration bin. There it is "tempered" or "steeped" without air flow for a minimum of 4 to 6 hours before being slowly cooled. The capacity of the heated air dryer increases since it is not used for cooling. In a batch dryer the cooling time is eliminated. A burner can be added to the cooling section of a continuous flow dryer to convert the entire dryer column to full heat.

Immediately after heated air drying, the outsides of the kernels are dryer than the centers. During the tempering process moisture equalizes throughout the kernel. Two to three percentage points of moisture are removed during the slow cooling process that follows the tempering period. By contrast, little water is removed during rapid in-dryer cooling. Because less moisture needs to be removed in the high-speed dryer with dryeration, more capacity is realized. The heat contained in the grain is more effectively used for removing water during cooling with dryeration, so that less fuel is required for the heated air dryer. The amount of moisture removed while cooling, is in proportion to the difference between the initial grain temperature and the ambient air temperature.

When using dryeration, the kernel stresses developed in the final stages of heated air drying and cooling are minimized. Stress cracking and kernel damage is reduced. Improved kernel quality as a result of dryeration produces grain which is less susceptible to damage during subsequent handling operations.

When using dryeration, the drying air temperature in heated air dryers may be increased since the grain is discharged at a higher moisture content. Also, it is in the dryer a shorter priod of time.

Increasing the drying air temperature increases dryer capacity and improves the fuel efficiency of the heated air dryer. If drying air temperature is increased, carefully check the grain quality (test weight, milling quality, germination or stress cracking) to ensure that satisfactory quality is maintained.

Savings in fuel and increased dryer capacity with dryeration depend on weather conditions, grain temperatures and moisture contents. Typically, a 20 to 40% savings in energy and a 50 to 75% increase in dryer capacity result. Actual energy savings and capacity increases depend primarily on the initial grain moisture content, as larger increases occur when drying lower moisture grain.

Normally, air flows in the range of 5 to 10 L/s per cubic meter are used for dryeration cooling. Lower air flows remove more moisture but increase the risk of spoilage.

After cooling is completed, the grain is transferred from the dryeration bin to aerated storage. During the tempering period condensation can build-up in the grain next to the bin wall. Grain that has completed the tempering period in the dryeration bins should not be left there for storage unless the bin has a fully perforated floor.

Management of Dryeration Systems

A separate cooling bin (or bins) is necessary for dryeration. The physical arrangement of the dryer and the cooling bins should facilitate switching from one bin to another and transferring of cooled grain to storage. Ideally, two or more cooling bins should be available, each holding a minimum 24 hour dryer capacity.

Hot grain is delivered to the cooling bin throughout the day and allowed to steep with the cooling fans off. After the first hot grain delivered to the bin has steeped for a minimum of 4 to 6 hours, the cooling fan is turned on while additional hot grain is delivered to the bin. Usually, the cooling fans are started in the evening if hot grain is first delivered to the bin in the morning. On the second morning, the dryer discharge is switched to the second dryeration bin. During the second day, cooling is completed in the first dryeration bin and the grain is transferred to storage. Alternate the cooling process from bin to bin on each succeeding day.

With larger capacity cooling bins, more than one day's drying can safely be accumulated before transfer to storage. For maximum benefits adjust the operation of the cooling fans to provide at least a 4 to 6 hour tempering period for all hot grain.

If only one cooling bin is used it should be large enough to hold several days dryer capacity. Hot grain is delivered to the bin, allowed to temper and then cooled daily. Each day more hot grain is added to the bin. Again, to provide the maximum benefit from dryeration, the operation of the cooling fan should be adjusted to provide at least 4 to 6 hour tempering periods for all hot grain. Some initial checking and testing of the specific cooling rate for the fan-bin system is required. Cooling fan operation can be controlled by a 24 hour timer or a one to two hour percentage timer which allows the operator to adjust the fan operating time to any percentage of the total period.

For dryeration, force the air upward through the bin so that it is exhausted at the top. In most cases, the cooling fan will be operating while the heated air dryer continues to deliver hot grain to the bin. If upward air flow is used, the grain in the lower part of the bin is not subjected to the heat and moisture which is removed from the last grain delivered in the upper portion of the bin. With upward air flow, heavy condensation on the roof and upper portions of the bin walls occurs particularly in cold weather. When the cooled grain is transferred from the bin, the small quantity of wet grain around the walls is blended with the remaining grain in the bin so that no storage problems result.

Systems should be well designed and managed properly. Accurate checks on moisture content of the grain before and after cooling and on temperatures of hot grain discharged from the dryer and cooled grain in the bins are necessary.

A bin probe thermometer is useful to monitor the cooling progress in the bin. Temperature cables are highly recommended for monitoring temperatures in bins of 500 cubic meters or larger. An indoor-outdoor thermometer with one bulb located in the air exhaust from the top of the bin is helpful in testing cooling progress. A low reading does not necessarily mean the bin is cool since the grain in the top center of the bin is the last to cool. It should be checked with a bin probe thermometer. Do not stop the fan as long as there is warm grain in the bin.

Caution should be exercised when inspecting bins during hot grain cooling. The hot, moist air coming off the grain can be hazardous to breathe. Do not climb into the bin under these conditions.

IN-STORAGE COOLING

In-storage cooling (figure 7) is another alternative to in-dryer cooling. Hot grain is transferred directly to the storage bin rather than to a special cooling bin as in dryeration. In-storage cooling eliminates the extra handling step which may be a disadvantage in dryeration. Although dryeration has advantages over in-storage cooling in terms of energy savings, dryer capacity, and grain quality, the elimination of the extra handling step required often makes in-storage cooling a feasible alternative.

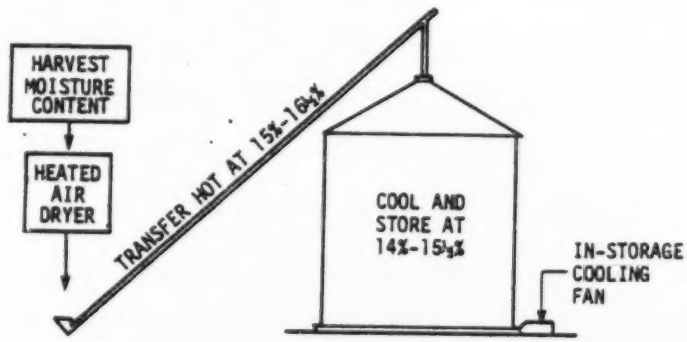


Figure 7 In-Storage Cooling.

Instead of cooling the grain in the heated air dryer, it is discharged hot to storage and cooled there. Experience shows that if the cooling fan delivers adequate air and is turned on immediately, grain can be cooled and stored in the same bin. Because cooling is delayed somewhat, the heat in the grain is used more efficiently for the removal of water. There is typically a 1% drop in moisture content during in-storage cooling. The biggest advantage of in-storage cooling is the significant increase in capacity which occurs when the cooling cycle in a batch dryer is eliminated or when the cooling section in a continuous flow dryer is converted to full heat.

In-storage cooling provides some of the advantages of dryeration without the extra transfer operation. However, when grain is to be stored in the bin in which it is cooled, a tempering period is

not recommended. If cooling is delayed, condensation can cause problems around the bin walls unless the bin has a fully perforated floor.

For in-storage cooling the fans must cool the grain as quickly as it is dried. The required air flow is the same as for dryeration -- about 5 to 10 L/s per cubic meter. Start the fan as soon as hot grain is delivered to the bin and continue to run it as long as there is warm grain in the top of the bin. Once the grain is cooled to the outside temperature, the fans are operated to lower the grain temperature to 0 degrees C in the late fall or early winter. Procedures for fan operation during subsequent storage periods are described in the section on aeration.

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